SILICON CHIP

MARCH 2016
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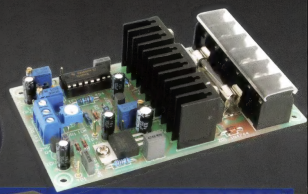

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SILICON CHIP MAGAZINE JUNE 2011 KC-5502

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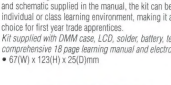
- 67(W) x 123(H) x 25(D)mm



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SILICON CHIP MAGAZINE JULY 2013 KC-5522

An easy way to test a USB port to see if it is dead, faulty or incorrectly wired to help prevent damaging a valuable USB device you plan to connect. Voltage is indicated using three LEDs.

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SILICON CHIP MAGAZINE DEC 2012 KC-5516

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- 3A max current

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SILICON CHIP MAGAZINE MAY 2007 KC-5446

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SILICON CHIP MAGAZINE SEPT 2013 KC-5523

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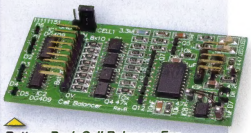

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Publisher's Letter

Future electronic developments in cars

Every month it seems there is some new development being introduced in cars to improve safety, efficiency or driveability. For example, many new cars now have adaptive cruise control, lane departure warning, rear cross-traffic alert, 360° camera view, automatic engine stop and restart and so on. Upmarket cars have head-up displays on their windscreen, some have auto reverse parking and many SUVs have rear cameras.

But it also seems that at least some of the electronic developments are trivial, such as touch-screens to control the phone, music and air-conditioning, while often eliminating the CD player. And do you really need a car with multiple 12V and USB outlets, to go with the multiple cup holders?

Overall, it seems as though at least some of the new features are just being added as marketing features, or they really only provide a fraction of what could easily be incorporated with the same hardware. For example, if a car has a rear camera, why isn't there an integral recording feature to an SD card? That way, you would have a video recording of any rear-end collision. In fact, the car's OBD system could add in the info for speed, brake and throttle settings.

It also seems rather silly to see brand-new cars fitted with after-market dash cameras. Why aren't such cameras already built-in? Some cars do have a forward-facing camera but no recording feature; that's just silly. Or if a car has in-built GPS satnav, why doesn't it give a readout of speed? Yes, in many cars there would be a discrepancy between the speedo which is often optimistic (under ADR specs) but the at same time the odometer is accurate. Why not the speedo too?

And if some cars have lane departure warning, why don't they have "lane keeping assist" as well? This is an easy manufacturing upgrade for all cars with electric steering. In fact, quite a few upmarket cars can be easily made to drive autonomously – check out the YouTube videos of this with a stream of Hyundai Genesis saloons.

But there are other potential developments which seem to have well and truly stalled. For example, what about electric braking? Is the conventional power-assisted hydraulic system, tied to the ABS and traction control systems still the best way to go? It seems as though electric braking, with servo-controlled pistons on the disc brakes could potentially be superior. In fact, why not extend some of the present dynamic energy recovery used in some cars for auto-start and restart, to do virtually all the braking?

More radically, do we even need the rear window on cars? Recent styling trends to smaller rear window glass have compromised rear vision anyway and if the rear window glass was totally eliminated, it would reduce solar heating of the car and the annoyances of cars with bright lights following too closely. In fact, rear vision cameras could eliminate internal and external rear vision mirrors.

And whatever happened to the move to 42V systems? That makes even more sense today with the greatly increased load on car electrical systems and the weight reduction that is now possible with lithium batteries. A lithium battery and a 42V (or close) system seems like a natural fit.

While all of this is going on, electric car sales are more or less going nowhere. This is only partly due to the current low price of fuel (which could easily change) but also relates to the lack of advantage of electric cars. Sure, you don't have to visit the petrol station and the cost of fuel (electricity) is quite low but most of the few available electric cars have limited range and are quite expensive compared to their internal combustion engine-powered equivalents.

Leo Simpson

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Source: Distributor Evaluation Study, UBM Tech, May 2015

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Beating the drum for Australian-made products

It was great to read your story in the January 2016 issue on Versatile Technology, regarding their manufacturing facility in Australia and them doing so well. Good on them.

It seems that there could be many other interesting stories about Australian companies and their on-going success in producing all sorts of products. It certainly belies the general belief among a lot of people that Australia "doesn't make anything any more".

Here at Altronics, we too have been manufacturing products in Australia at our Perth headquarters for many years. We have a department dedicated to manufacturing our range of "Redback" public address amplifiers and associated equipment, thousands of which are made each year.

These are installed in the premises of corporate customers such as Bunnings, Masters Hardware, Coles, Kmart, Dan Murphy's, schools, hospitals, clubs and all manner of other places and we also sell them overseas.

We know we could source similar products from SE Asia but generally these items fall way short of what is expected here in Australia in terms of quality, reliability and features. We are so confident in our product quality that we offer an industry-high 10-year

warranty on our locally made Redback products.

We employ some very clever people, who design the products from conception, including electronic and mechanical design, through to the assembly process. Naturally, not everything is done in-house, as we outsource metal-work and PCB assembly to local Perth specialists.

Further to our own manufacturing department, Altronic's parent company Altronic Distributors, supplies hundreds of companies, large and small Australia-wide, with its range of components, connectors, transformers and enclosures. All of these companies are manufacturing a variety of niche products and employing thousands of tax-paying people. Now that must be good for the country and the economy!

Brian Sorensen,
General Manager,
Altronic Distributors Pty Ltd,
Perth, WA.

Binary fluid steam power plants not mentioned

I have a few comments to make regarding Dr David Maddison's series of articles, the most recent appearing in the December 2015 issue and concerning Super-Critical and Ultra-Super-Critical Steam Power Plants. I was somewhat astonished that he made no mention of binary working-fluid power-plants as exemplified by the Kalina Cycle and for which there are several operational examples around the world. So much so that I actually wondered if Pt.2 was missing! These web links will fill you in:
www.physics.hmc.edu/~saeta/courses/p80/oldwiki/files/16042.pdf
https://en.wikipedia.org/wiki/Kalina_cycle

As an aside, attempts to improve the basic efficiency of steam boilers are not restricted to utility power-plants, as a most novel and by all accounts, effective system was trialled around the mid 20th century (no doubt spurred on by the rebels opposing the 'dieselisation' zealots fast encroaching on sacred territory!) to improve (ie, reduce) the fuel consumption of coal-fired steam

Solid state amplifiers superior to valves

I am a long-time reader of your magazine (my collection also includes *Electronics Australia* and the last few editions of *RTV&H*) and this is the first time I have been tempted to drop you a line. I guess you can appreciate my interest in the Currawong Valve Amplifier (SILICON CHIP, November & December 2014, January 2015) and the new valve preamplifier in the January 2016 issue.

Having picked up the latest copy, I fast-forwarded to the article, probably more for sentimental reasons than anything else, but I was stopped in my tracks at all the (red) negative values for the operating voltages around the 12AX7s. I built up a number of circuits using these valves in the 1960s and was beginning to wonder if you knew something that I didn't, until I checked all the component polarities which conformed to expectations.

It's interesting to revisit the old technology and look at some fresh concepts for power supplies but I do not regret the passing of the thermionic valve with all its inefficiencies. Despite all the complexity, the modern solid-state device is inherently more reliable and sounds pretty good to my ears.

Keep up the good work. You guys have been my unofficial textbook over the years. I think my next project will be that nice BIG CLOCK you have just finished describing.

Owen Goodrick,
Tauranga, NZ.

Comment: although not obvious at first glance, the "minus" signs in front of the voltages on the valve preamp circuit are in fact "approximate" symbols. We'll try to make these easier to distinguish in future.

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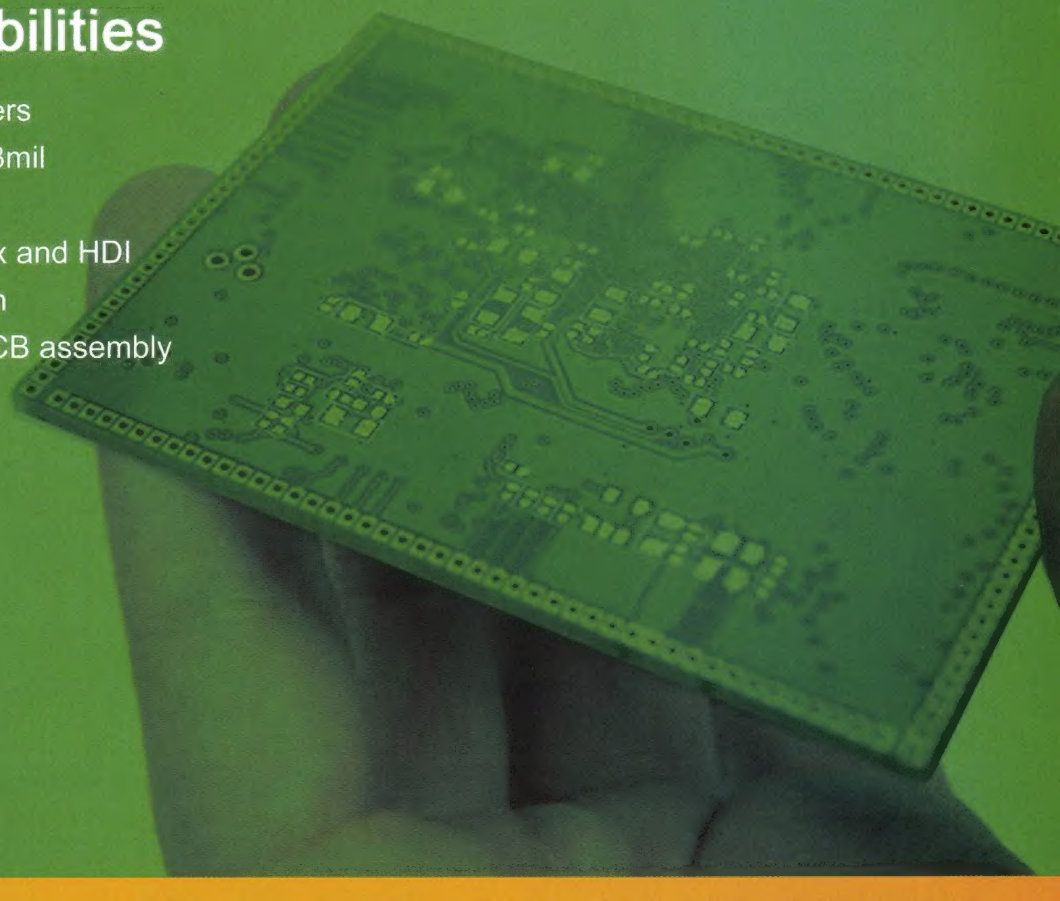

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Mailbag: continued

IR remote control over Ethernet

I have TV sets in some bedrooms and two living areas. Some of the TVs have internet access and streaming while others have internet access and streaming by use of set-top tuner/recorder units. As each TV set or tuner/recorder unit provides different services, depending on the brand, I wish to get a greater choice but without having to purchase a number of set-top boxes for each TV set.

Incidentally, the internet services offered for each brand change so rapidly that I believe that it is better to keep a good TV set with a good display and simply buy new streaming units of various kinds which are much cheaper and can be replaced often and stay up to date.

The solution I wish to employ involves mixing my off-air antenna signal with signals from various set-top boxes and an Apple TV and whatever else comes along to connect to services like Stan, Presto, Foxtel, etc. With the appropriate mixes and using different channel frequencies out of each device and with the appropriate amplifiers (and digital modulators), I can transmit over my coax distribution to all of my TV sets. This will mean I will only need one of each set-top unit for the house which could be shared by all of the TV sets. Aftermarket remotes could be purchased fairly cheaply to be placed with each TV.

The next issue is how to control the set-top boxes remotely. There are many wireless devices available but they are expensive and unreliable in big houses with lots of steel. Each TV set has Ethernet/internet available. This would be necessary if one hoped to stream to each TV set anyway. What I seek are infrared sensors to receive the IR signal at each TV set and then transmit it over Ethernet and at the location where all the set-top boxes are, with an IR transmitter relaying the signals.

There are a number of devices which offer to do this over Cat5; some even imply that they can be compatible with the normal Ethernet network and even go through a low number of switches.

However, what they do is not clear. I am looking for a device which will truly relay IR signals over standard Ethernet. In many places, I am unable to lay Cat5 or Cat6 cable, particularly in the lower storey with a slab and a second floor above it, so that the internet is delivered to most of the TV sets by wireless, hence the need for true Ethernet.

This would be sufficient for my purposes, however a bonus would be if the units could also transmit HDMI including sound, or composite and sound signals as well. Again, there are many devices which handle Cat5 but not real Ethernet.

It occurs to me that there could be many others who may wish to achieve similar things and would like a unit as I have suggested to build. I believe this could probably be done economically using Arduino components. Ethernet modules are already available, as are infrared sensors and transmitters.

Stan Condy,
via email.

Comment: what you propose sounds like a good strategy but it may not be easy to implement, both as far as mixing the signals from the various boxes with the off-air signal is concerned and then also having the remote signals passed back to the central location of all the boxes.

locomotives. Have a look at this link on the Holcroft-Anderson Recompression Locomotive:
www.douglas-self.com/MUSEUM/LOCOLOCO/holcroft/holcroft.htm
and this link to Wikipedia on advanced steam technology:
https://en.wikipedia.org/wiki/Advanced_steam_technology#Holcroft_and_Anderson

Referring to his previous article in the November 2015 issue, concerning organic electronics, on page 18 he makes reference to PVC. This material was first discovered in 1838, "re-discovered" in 1872, then formally iden-

tified and patented in 1913. It is interesting that one of its first early uses was to for "protective" outer-suits, as worn by conscripted foreign workers employed in Japan's chemical weapons arsenal in the 1930s.

Andre Rousseau,
Papakura, NZ.

David Maddison comments: I have spent some time looking at this and believe the Kalina cycle is good for utilising low-grade heat such as in geothermal production or waste heat recovery. This is where the power stations based on this cycle are used but they are very low power, such as 4MW.

Because of its lower working temperature, it cannot reach the high temperatures of steam used in primary electricity production. This is why it is not used in large-scale power plants, many of which have been designed since the development of the Kalina cycle in 1984.

Over-wind solution for transformer over-voltage

Regarding the enquiry by D. L., in the Ask SILICON CHIP pages of the January 2016 issue, on excessive voltage for SC480 amplifier, I thought I would offer a solution I have used several times to "adjust" toroid voltages. It simply involves adding turns by hand over the wrapped windings, usually equating to around 0.4V per turn.

Then you simply add or subtract the "wound-on" voltage by series-wiring to the secondary, either in phase or out of phase, to add or subtract the voltage. In the case of D. L, two windings will allow one for each half of centre tap, and in this case only about five or six turns each would do it. Just make sure the windings that are added are at least the same gauge as the original secondary.

Alasdair McCarter,
Glen Huon, Tas.

Question on hybrid solar system

I am a regular reader of your magazine and your article about the Hybrid Solar System, in the October 2015 issue, was excellent. Good on Geoff Woodman for designing a great system and giving you the opportunity to feature it in SILICON CHIP magazine.

What I would like to know is how the system synchronises to the grid when power is restored after a blackout?

Gerard Gibbons,
Buff Point, NSW.

Geoff Woodman replies: the contactor solenoid is powered from the grid, and must be energised for the system to be connected to the grid. If there is a grid outage, the contactor drops out, isolating the island grid, and reconnection is only possible once the grid is restored.

GPS in-dash satnav limitations

I write in response to the recent Mailbag discussion relating to why in-dash satnavs are more costly, updated much less frequently and are often less capable than standalone units.

First, standalone units have a short development to production timeline; as little as six months. The most they have to worry about is getting the data sources' licensing signed off as quickly as possible. Even so, frequent and plentiful updates are warranted just on sheer numbers.

A vehicle is a very different beast. Sections of the vehicle design could see 10 years before production. Then, not only is the electronics not "just" for satnav, but for pretty much all of the processor-mandated functions the car is capable of.

As the electronics is updated to deal with new features the vehicle may have, the end user has to trust the satnav functionality is backward compatible with new data. Did the vehicle manufacturer cater for this? "Good luck with that", as the saying goes.

And the editor is correct, in stating on page 8 of the February 2016 issue, that in-dash units are prevented from showing speed. One could say this is because you're doubling functionality but the cynic in me says it would only show-up the sometimes glaringly incorrect speedo needle indication.

John Tzerkeris,
Croydon Park, NSW.

More on how a loudspeaker operates

With regard to the discussion in the Ask SILICON CHIP pages of the February 2016 issue, about how a loudspeaker operates, at very low frequencies the speaker cone displacement will in fact follow the instantaneous voltage as described. But at somewhat higher frequencies, the velocity of the cone follows the voltage. That is to say, when a sinewave drive voltage reaches its peak, the cone is going through the mechanical zero crossing at maximum velocity, just like a pendulum at the lowest point of its swing.

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Mailbag: continued

Two-foot driving negates the QuickBrake

I read the article on your new QuickBrake project in the January 2016 issue and am wondering if the idea is based on a false assumption.

If I understand it correctly, it relies on the delay between lifting your right foot off the accelerator and applying the brake with the same foot. This assumes that everyone uses this same driving technique and I am referring to driving a vehicle with automatic transmission. Some drivers, and I am one of them, use two feet when driving; the left to operate the brake and the right for the accelerator.

In this case, is it not possible that the brake is applied before the accelerator is released? We are talking about milliseconds here after all. Would QuickBrake still operate in these circumstances or with the same improvement in delay time?

Syd Read,
Hastings, Vic.

Comment: some people do drive like that and in some cases they sometimes actually drive with their foot lightly on the brakes while they still have their right foot on the accelerator. This is a generally a bad technique because it can lead to increased fuel use and brake pad wear, and it gives a misleading indication to a following driver. It could also mean that the QuickBrake would be largely negated; it would not work because the brakes are already applied! Not that any extra harm would be done.

On the other hand, if your left foot is not actually on the brake, it is possible that your reaction time in lifting your right foot off the accelerator and then applying the brake with your left foot may still be quite long. Without doing some controlled tests, it is not possible to say what improvement the QuickBrake might give in this situation.

However, we suspect that the time to actually apply the brake (and the brake lights) with your left foot may still be quite a bit longer than the action of the QuickBrake. It might even be longer than if you drive in "single-footed" mode. Think about it: in order to approach the actuation time of the QuickBrake, your left foot would need to apply the brakes before you have fully lifted your foot off the accelerator.

The cone displacement would be lagging the voltage by 90°. One might expect that this peak velocity produces peak pressure in open air, a derivative of the velocity, so the voltage ends up producing a corresponding air pressure. I'm sure there is more to it than that.

It reminds me of a "Let's Buy An Argument" column in *Radio TV & Hobbies* way back, regarding what shape of groove would be needed on a phonograph record for a magnetic cartridge to produce a square wave. The answer was a triangular wave. So too, a sinewave record groove would produce a sinewave but phase-shifted by 90°.

Graham Pratt,
Hampton Park, Vic.

Comment: you have raised an interesting point. In fact, the motion of the loudspeaker cone will certainly be modified by the complex load presented by the speaker to the amplifier and that includes the effects of the crossover network and the enclosure itself. And the previous discussion also ignores the effects of cone breakup, wave propagation in the cone and interference effects between the various drivers in enclosure.

As far as the recorded waveform necessary to obtain a square signal from a magnetic cartridge is concerned, the answer is somewhat more complex than a "triangular wave". It is true that the RIAA equalisation circuitry necessary for magnetic cartridges can be regarded as a differentiator. And it is true that if you feed a triangular waveform signal into a differentiator, the output will be a square wave.

In reality though, the RIAA equalisation characteristic (with the IEC modification) has four time constants of 7950µs (20Hz), 3180µs (50Hz), 318µs (500Hz) and 75µs (2122Hz). This means that the shape of the groove waveform will not only be more complex than a simple triangular waveform but will also have quite a different shape at lower frequencies.

These days, a simulation could easily produce the actual waveforms.

QuickBrake revisions & refinements

The QuickBrake project featured in January 2016 issue is a great idea but its potential to reduce rear-end collisions is significantly reduced by the conditions under which it won't trigger.

Here are some ideas for QuickBrake V3. The primary purpose of brake lights is to reduce the chances of a rear-end collision. Having the brake lights illuminate when the driver steps on the brake pedal is an incomplete implementation of this purpose. The QuickBrake improves on this simplistic idea by detecting other reasons for the car slowing.

What if we step away from the actions of the driver and decide that the brake lights should flash or come on when the following vehicle has a following distance of less than three seconds? Then even if our car isn't slowing at all, if another vehicle approaches too closely from behind, the other driver will receive a clear warning to slow down.

This would require a reasonably sophisticated sensor to reliably detect the distance to the following car (up to 92 metres for a 3-second gap at 110km/h). In particular, cars travelling in other lanes would have to be ignored. It may also not be legal or desirable to use the brake lights this way, since they might tend to flash a lot and lose their impact.

In this case, I suggest that the QuickBrake could provide signalling additional to the existing brake lights. Something like a large scrolling LED sign mounted in the rear window that can display messages like, "Thank you for keeping your distance" and "Gas cylinders on board. Please increase your following distance to at least three seconds" (the latter message is a little tongue-in-cheek, but it might make an aggressive driver back off out of self-interest).

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Mailbag: continued

Standing power measurements for air-conditioning seem very high

I refer to a letter in the Mailbox pages of the February 2016 edition, page 10, from Rodney Champness, regarding split system air-con units in standby mode. The measurements quoted seem unbelievable for a modern-day appliance; hundreds of dollars per year in consumption whilst not operating!

I take it that the air-conditioner unit was just ready to run on pressing the "Start" button on the remote hand-set, and the air-conditioner's modern innovation of a variable speed and capacity compressor, was not already up and running, quietly, in the background?

I connected my "Watts Clever" meter in circuit with my recently-installed Fujitsu split air-con system, of the same 7100 watts cooling capacity mentioned in the contributor's letter, with the system previously switched off using the remote hand-set "Stop" button. The reading was typically around 7-9W. Last summer, when I completed the installation, that reading was 8W on a 35°C day!

By the way, I've found the Jaycar "Watts Clever" inexpensive digital power meter to be acceptably accurate, when compared to nameplate values on various appliances and taking into consideration that my mains voltage is a bit on the high side, ie, around 252VAC at low demand times, or with all those PV panels around.

Robert Sebire,
Emerald, Vic.

If the QuickBrake detects that the following vehicle is less than three seconds away, a warning could also be displayed to us to enable evasive action to be taken, including pulling over to allow the tailgater to pass, or at least increasing our own following distance.

If we have gone to the trouble of designing this thing to detect the car behind, it should then be a straightforward matter to apply it to the car in front, to give the driver a warning if our following distance is too small.

In this case, the minimum following distance could be the greater of three seconds and six seconds, minus the following distance of the car behind us, to minimise our risk of becoming the meat in a metal sandwich.

Andrew Partridge,
Ermington, NSW.

Comment: we like your concept for QuickBrake V3 but that would require a considerably more complex design involving a LIDAR or radar sensor to compute the distance to the following vehicle, a GPS module or other means of measuring speed and so on. Whether such a system would work on curves is problematic as the rear-facing sensor is unlikely to be steerable.

Unsteady hands make SMDs difficult to solder

I wonder if you can offer any assistance for older people where their hands have an unfortunate tendency to shake when performing fine tasks, although they may be quite steady under most conditions? Whilst this lack of steadiness sometimes shows itself during some of my finer electronics construction, I have accumulated an assortment of clamps, vices, brackets and the like with which to accomplish assembly.

In my working lifetime I have gone from computers using relays and Boolean logic to microprocessors so I recognise the inevitable march of progress and generally applaud it. However, in contemplating the move from through-hole to surface-mount techniques, I am concerned about soldering even the simple passive devices, let alone multi-pin ICs. I should not like to abandon my electronics hobby so I need to find some way to move to the next generation of the technology.

I have read the articles published in your magazine regarding surface-mount soldering techniques, stereo microscopes and the like but I could find little reference to component holding techniques and other aids for people with unsteady hands.

Therefore my question is: are there

such aids to assembly which can assist people with the transition to surface-mount technology and can you suggest where I might find them?

Barrie Davis,
Hope Valley, SA.

Comment: this is a widespread problem and not confined to older people. If other readers have worked out solutions, we would love to know about them.

More on balanced cables

In the Ask SILICON CHIP pages of the February 2016 issue there is a letter from P. J. about an earth hum problem with his laptop and a venue's PA system/amplifier. This is a problem I have encountered many times in church set-ups with laptops, PCs and VCRs & DVD players, etc.

Basically, anything not designed for the pro audio desk with a 230VAC supply may cause earth noises and hum. With respect to P. J., I think he may be trying to over-think the issues. While a good DI box will almost always solve the problem, most laptops and many hall type PA systems do not have balanced inputs or outputs. Going to optical isolation is way too complicated.

My recommendation to P. J. would be to search for "Audio Isolator" on eBay and he will find a range of cheap isolating units complete with plugs and cables for his laptop. This one is less than $10: www.ebay.com.au/itm/Car-Accessory-3-5mm-AUX-Audio-Ground-Loop-Isolator-Noise-Filter-Killer-Pop-/231540622385

While I have not bought this one, we have several similar ones in our church set-up and they all work well!

I would also carry a range of plugs and adapters for balanced and unbalanced and a DI box but just the eBay isolator above and a 3.5-6.35mm adapter will solve most problems on over 90% of the systems I have seen.

Russell Martyn,
Adelaide, SA.

Biasing a class-A or any valve amplifier

I'm sure you will have received a number of remarks about J. C. from point Cook Vic, who asked a question in the January 2016 issue about biasing a class-A tube audio amplifier. He wanted to do cathode bias with an electronic control, not a variable resistor. A current sink was suggested by SILICON CHIP but this is not a good idea.

Let's look at some issues. One advantage of using a resistor for cathode bias is that it results in negative feedback, both AC and DC. From the DC perspective, this tends to stabilise the average cathode current for different tube specimens to a more similar value.

However, to maintain the stage gain, it is usually necessary to bypass the resistor with an electrolytic capacitor, typically 22μF to 47μF, to eliminate the AC component of the negative feedback, or degeneration, caused by the cathode resistor. On the down-side, the DC voltage or "bias voltage" developed across the resistor subtracts from the available HT voltage which reduces the maximum power output.

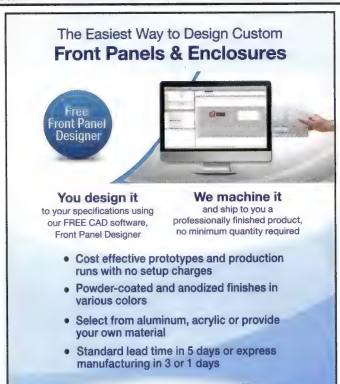
If a current sink was placed in the tube's cathode, as suggested by SILICON CHIP, the tube's amplification would drop to nearly zero, because a current sink or source has a very high impedance to AC and any changes in plate current for any grid drive voltage would be eliminated. So if that was used, to get any amplification, the current sink would have to be bypassed, just like a cathode resistor, with an electrolytic capacitor.

What is needed is a "voltage source" which has a low internal resistance to AC. But it is actually illogical to place it in the cathode circuit anyway because it is then in series with the tube's load and subtracting from the available HT voltage. J. C.'s intuition was correct as he was worrying about the cathode circuit being in series with the output transformer.

The tube bias is set by the grid-to-cathode potential. So it is much better to add the required voltage source in series with the tube's grid to ground return resistor in the ground end, as a negative voltage. This is called "fixed bias". The advantages are many. The tube's cathode can be grounded (making better use of the available HT voltage), it eliminates any heat dissipation from the cathode resistor and the bias supply need not be able to supply significant current as the tube's grid current is usually negligible.

In vintage battery radios and amplifiers, for example, bias batteries were used to supply negative grid biases as every HT volt came at a premium due to the cost of batteries. The bias batteries lasted for their shelf life.

There are many other ways to get this negative volt-



Mailbag: continued

Solar systems need more panels

I found Steve's Lansell's letter in the Mailbag pages of the January 2016 issue to be spot-on. I have worked through similar issues myself. My initial solar system consisted of a 5kW inverter "matched" with 5kW of solar panels and this was increased two years ago to 7.5kW. Monitoring of my ROI (return on investment) showed an improvement of 33% for the 50% solar panel increase.

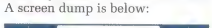
I can monitor my installation at: http://pvoutput.org/intraday.jsp?id=30164&sid=27624

When solar power exceeds inverter power, the MPPTs (maximum power point trackers) in the inverter raise the working voltage of the array until it reaches the roll-off point, the efficiency of the array is reduced, and the array produces less power.

Inverter temperature on hot sunny days has been reduced by the addition of 24V fans controlled by a 45°C Jaycar thermostat.

A Raspberry Pi has been used with a program called SBFSpot for the last two years to access my inverter, and upload the data to the above website. A "Clever Watts" EW4008, connected to another Raspberry Pi, was hooked up three months ago to capture my household consumption and upload it as well. The accuracy of the EW4008 was poor and it was replaced with a $40 Eastron SDM220-modbus electricity meter to give very accurate data.

A web server on the Pi allows me access to live data on the SDM220 from any internet connected device. A screen dump is below:



Lonsdale Live Power Readings
Use REFRESH to update

* * * 2016/01/10/ 10:00:49 * * *		
Volts =	248.98	Volts
Amps =	4.39	Amps
Active Power =	1061.19	Watts
Apparent Power =	1092.35	VoltAmps
Reactive Power =	266.33	Var
Power Factor =	0.97	
Frequency =	49.96	Hz
Active Energy =	1628.45	KwHrs
Solar Inv. Pwr =	4538.0	Watts

The PVOutput website is designed primarily for grid-connected systems but it is still very useful for off-grid sites. My daughter, son-in-law, and their children live off-grid and rely on solar, wind and diesel for their power. I have set up a Raspbery Pi at their location, equipped with an ADC shield from ABElectronics in England. Their system is basically 12V, with 12V-to-230VAC inverters. The ADC on the RPi gets its "current" inputs from three 150A Allegro ACS758s.

PVOutput allows extended data points to be used for a small donation. This allows for the generation to be split into solar and wind. At present, diesel charging is combined with the wind.

PVOutput has rules that ensure "generation" power figures are not higher than the system size. There is no option in PVOutput to add the wind component to the system size, so the solar size had to be doubled to ensure that the total generation figures would not be rejected.

Again, a web server on this remote RPi is very useful. Below is a screen dump from my phone:

Wondecla Live Power Readings
Use REFRESH to update

* * * 2016/01/10 14:17:20 * * *				
Input	Function	V_Read	Calc_E/I	Watts
1	Batt Volts	0.13019	13.02	
2	Load Amps	2.06606	29.2	380.0
3	Solar Amps	1.21249	90.5	1177.6
4	Wind Amps	1.30500	85.1	1107.5

This remote RPi also sends my son-in-law (and me) an email every morning with a summary of the last six days of data. This is very useful to get an idea on how the batteries are holding up, without having to log onto PVOutput.

I have glossed over the many, many hours spent writing Python scripts to do all the things mentioned above. My Python programming ability is basic at best and my scripts are messy but they work.

Sid Lonsdale,
Cairns, Qld.

age. One is to place a resistor (R) in the ground return of the amplifier's HT supply, where the average HT current is I, so that the IR voltage drop is available as a negative bias. It can be filtered and a control added. Or it could be made available from one of the power transformer's windings with additional rectifiers.

Another simple way, if 12V DC is present, is to wire up any convenient IC as an oscillator, like a 555, running above the audio spectrum, say at 30kHz, and put a diode-capacitor voltage multiplier on that using 1µF capacitors and 1N4148 diodes. Or just buy a pre-made DC:DC converter module (they would need additional output filtering as they are often good noise sources).

In any event, fixed bias is the superior way to go but unlike resistor-cathode bias it does sometimes require individual adjustments for individual tubes and needs to be tweaked for tube ageing. But in many cases, adjustments are not needed at all once it is set for a specific tube type.

Perhaps I should also mention that some tube amplifier designers have a fondness for using a cathode resistor un-bypassed (no capacitor across the cathode resistor in class-A tube output stages); the degeneration and negative feedback lowers the distortion and of course, the gain. Also some push-pull stages use cathode signal coupling so they cannot have a bypass.

There is one application with tubes though where it is folly not to use a cathode-bypass electrolytic capacitor. That is for a tube in the front end of an amplifier (high gain), typically with a magnetic cartridge phono input, for example, like an EF86, 5879

or EF37A where the heater is run from the usual 6.3VAC.

In this case, small amounts of heater cathode leakage in the tube can cause significant audible hum and the cathode bypass capacitor is always needed for that reason. A lot of modern tube amplifier makers run the heaters from DC, so it's not a worry in that case.

Hugo Holden,
Maroochydore, Qld.

Light curtain clarification

I have received my copy of the December 2015 issue which features my circuit for a Light Curtain to prevent garage door damage, on pages 88 & 89. Unfortunately, the description of the Light Curtain is incorrect and this mistake will make it hard for readers to understand its operation.

The mistake involves the operation of the IR receivers. At no time do their outputs go low and stay low. The output is a 1kHz square-wave when there is no obstacle in the way of the infrared beam and it goes high and stays high if the beam is broken. The detectors feed Q1 and it is its output that goes low and stays low when the beam is broken.

Alan Chamberlain,
Charlestown, NSW.

Practical solution to blown headlights

On page 94 of the January 2016 issue, there is a request for an overvoltage protector to prevent car head lights from blowing frequently. This reminds me of a nephew's car with a similar problem, which was due to poor connection between the H4 globe and the socket, causing over-heating of the filament.

The problem was solved by tightening up the spring connectors or replacing the socket on the wiring loom and resoldering wires.

John Murphy,
Glen Waverley, Vic.

Comment on Speech Timer project

Like your author, I too have seen some "interesting" timers used in contests, with some of the mains-powered ones verging on the illegal!

However, if I was the chief judge in a contest where the SILICON CHIP Speech Timer was being used, I would insist that the display not be visible to the audience, as it would be too easy for a member to communicate (whether knowingly or not) the elapsed time to the contestant. The actual speech time is confidential to just a few officials and Toastmasters International can be quite strict at times.

Dave Horsfall,
North Gosford, NSW. SC

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QUANTUM COMPUTERS

"No, you're not going to be able to understand it... You see, my physics student don't understand it either. That is because I don't understand it. Nobody does. The theory of quantum electrodynamics describes Nature as absurd from the point of view of common sense. And it agrees fully with experiment. So I hope you can accept Nature as She is – absurd."

(Nobel laureat Richard Feynman, 1985)

Quantum computers are based on a different type of architecture to conventional computers and can solve problems using the strange properties of quantum mechanics such as superposition and entanglement.

By Dr David Maddison

In recent times computers have become enormously powerful and can be used to solve extremely complicated problems such as in fluid dynamics. But the architecture of conventional computers is unsuited for certain classes of problems.

Solving those problems would take impractically long periods of time or be altogether impossible.

Examples of problems that quantum computers could or should be good at solving include simulation of quantum mechanical systems. For example, it may be possible to accurately simulate interactions that occur in a particle accelerator such as the large Hadron Collider. Chemical reactions could also be simulated including extremely complex ones like photosynthesis.

New drugs could also be developed more quickly because large numbers of configurations of drug molecules could be evaluated quickly and the ones most likely to work selected for further testing.

They could be used for breaking of certain types of encryption codes (with Shor's algorithm, for example) or searching very large unsorted databases (with Grover's algorithm). A classic example given is searching a phone book for a certain phone number when the name is not known. If a book had one million numbers it could be searched in

one thousand steps with a quantum computer instead of on average one half million steps as with a conventional computer and a naive search method!

Weather forecasting and climate models are other possible uses. There are huge numbers of ways that different parts of a weather or climate system can interact. A quantum computer could analyse all possibilities at once and find the optimal answer.

Travel routes and schedules could be quickly optimised. For example, for the classic "travelling salesman problem" the order of which cities to visit in order to minimise the distance travelled and not to visit any city twice could be quickly evaluated. A commercial quantum computer, the D-Wave Vesuvius solved such a problem in less than half a second compared with a conventional computer which took 30 minutes.

Other possible uses include machine learning, pattern recognition, image classification and analysis, optimisation problems, quantum communication for guaranteed privacy and quantum teleportation where information is transferred from one quantum system to another with no wires, radio or light transmission.

Note that quantum computers are unlikely to replace the computers we use now but will coexist with them and be used only for the types of problem they are best at solving.

Quantum mechanics

Before discussing how a quantum computer works it is first necessary to discuss some basic principles of quantum mechanics. Quantum mechanics is a branch of physics that describes the behaviour of the very small objects such as atoms, sub-atomic particles and photons and is distinct from traditional classical mechanics that describes the behaviour of larger scale objects.

In classical mechanics, objects exist in a specific and definite place and time, something we are all used to. But in quantum mechanics, particles exist in a "cloud of probability" so that the location of a particle is described by a probability distribution.

In addition, in quantum mechanics, particles are restricted to certain particular values of properties such as how much energy they have or a property known as spin where a particle must be either "up" or "down", much like the north or south on a compass.

The values of the properties of particles are regulated like the clicks on a dial and are said to be quantised. Another main property of quantum mechanics is that elementary particles sometimes act like waves and at other times like particles, so-called "wave-particle" duality.

There is also the uncertainty principle which states that for a given particle we cannot measure with precision its properties of both position and its momentum. The more accurately one value is known, the less accurately the other is known. In fact, accurately knowing these two properties together is a meaningless concept in nature.

Any attempt at measurement of one property will alter the other property of the particle so it is impossible to ever know both values. Incidentally, this uncertainty also applies to macroscopic objects but is so small as to be of no consequence, eg, the uncertainty of position of a thrown cricket ball would be around 10^{-30}mm.

Superposition is the condition whereby a particle can be in a combination of two or more quantum states simultaneously. For example, rather than having a spin of "up" or "down", an electron can be (3/5) up or (4/5) down. In this case, the RMS sum of the coefficients must remain as one.

If up and down corresponded to the binary numbers zero and one we would say (simplistically) that it partially had the values of zero and one at the same time. Any attempt to read or measure the value of the particle, however, causes its quantum state to collapse or de-cohere into one of the values it possesses such as a "one" and superposition is lost. This phenomenon is known as quantum decoherence.

While superposition is a characteristic of one-particle systems, a property that pairs or groups of particles can have is entanglement. In this case the quantum state of the pair or group is described collectively as it is shared and it is not possible to describe the state of an individual particle independently.

Consider a pair of entangled particles which are known to have a total spin of zero. These entangled particles are

How safe is encryption against attack by a Quantum Computer?

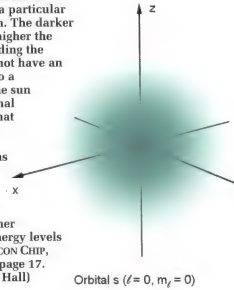
It has been claimed that quantum computers will be able to break certain types of cryptography by their ability to factor large numbers which are the basis of certain types of encryption schemes.

Schemes claimed to be at risk include those based on symmetric key algorithms (block cyphers) and asymmetric public key algorithms (RSA, DSA, ECC).

Acknowledging the risk, the US National Security Agency has already announced it will be moving toward using encryption schemes which are resistant to attack by quantum computers.

It should be noted that for the foreseeable future, there are no conceivable realistic quantum computers that are able to come close to factoring the numbers required to break the above schemes (when the key length is long enough) so they should be safe for a long time.

For example, using Grover's algorithm to factor a large number would enable the calculation to be done in the square root of the time taken by a classical computer (say 10 days instead of 100 days) but the security of the encryption could be maintained if the key length were doubled which is relatively easy to do.



Orbital s ($\ell = 0$, $m_\ell = 0$)

The probability distribution of an electron in a particular orbital of an atom. The darker the "cloud", the higher the probability of finding the electron. It does not have an orbit analogous to a planet orbiting the sun as in the traditional simplistic view that many people are familiar with although electrons will have the highest probability of being at certain energy levels. For a further explanation of energy levels in atoms see SILICON CHIP, November 2015, page 17. (Image credit: RJ Hall)

SOME SIGNIFICANT DEVELOPMENTS IN THE HISTORY OF QUANTUM COMPUTING

There are far too many developments relevant to quantum computers to list them all here, so only a selection is given.

1975 RP Poplavskii showed the impossibility of simulating quantum systems on classic computers due to superposition.

1976 Roman Stanisław Ingarden published work on quantum information theory.

1980 Yuri Manin proposed the idea of a quantum computer in his work "*The computable and the non-computable*" (in Russian).

1981 Richard Feynman said in a talk that it seemed impossible to simulate quantum systems on classical computers and proposed a basic theoretical model for a quantum computer. For those interested they can read a transcript of this talk at **www.cs.berkeley.edu/~christos/classics/Feynman.pdf**

1982 Paul Benioff proposed a comprehensive theoretical model for a quantum computer.

1985 David Deutsch described a theoretical model of universal quantum computer that can be used to model other quantum computers and the algorithms they use.

1991 Artur Ekert invents secure communication based on quantum entanglement.

1993 Dan Simon invents a problem that would be exponentially faster for a quantum computer to solve than a classical one.

1994 Peter Shor, incorporating Dan Simon's ideas from above, discovers a method to factor large integers quickly. The factoring of large integers is the basis of many modern cryptography systems such as credit card transactions and this algorithm could theoretically break many such systems. This lead to a tremendous interest in quantum computation.

1995 Peter Shor and Andrew Steane propose a method for quantum error correction. Also Christopher Monroe and David Wineland experimentally produce the first quantum logic gate based on a trapped atom.

1996 Lov Grover invents a quantum algorithm to search databases that is much faster than would be achievable on classic computers. David P. DiVincenzo published a list of the physical requirements for a quantum computer.

1998 First demonstration of a quantum algorithm run on a two qubit quantum computer. First three qubit quantum computer invented. Grover's algorithm (1996) run on quantum computer.

2000 First five qubit and then seven qubit quantum computer and also partial execution of Shor's algorithm (1995).

2001 Full execution of Shor's algorithm (1995) to factor the number 15.

2002 Quantum Computation Roadmap developed to facilitate the future development of quantum computation. The document is constantly updated. See **http://qist.lanl.gov/qcomp_map.shtml**

2003 The US Defense Advanced Research Projects Agency (DARPA) implements a quantum network using optical fibres to transmit information securely using entangled photons. Any attempt to improperly intercept the data will result in a loss of entanglement of the photons and an inability to read the data. Also the University of Queensland demonstrate quantum NOT gates.

2005 First quantum byte created, known as a qubyte.

2006 First 12 qubit quantum computer.

2007 Commercial company D-Wave Systems announce working 28 qubit quantum computer.

2008 Qubits based on graphene quantum dots. D-Wave Systems announce working 128 qubit quantum computer chip.

2009 Qubits with lifetimes of hundreds of milliseconds. Google and D-Wave Systems collaborate in the area of using quantum computation for image searches.

2010 Single electron qubit demonstrated.

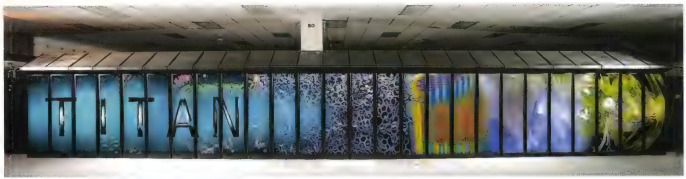
2011 D-Wave produces first commercial quantum computer. Error correction in quantum processor developed. Decoherence minimised using high magnetic fields. Record low error rates are achieved for a quantum computer. An error rate of one in 10,000 logic operations was considered a benchmark target but a rate of one in 50,000 was achieved. A group at the University of New South Wales and the University of Tokyo achieve a breakthough in quantum teleportation, successfully transmitting quantum information without error or affecting the superpositions of qubits.

2012 D-Wave produced quantum computer with 84 qubits. Single atom transistor developed. 1QB Information Technologies founded, the world's first company to write quantum computer software. See **www.1qbit.com/** Decoherence was kept suppressed for 2 seconds. A group at the University of New South Wales develop the first qubit based on a single atom of silicon which would enable quantum computers to be built in silicon like conventional computers with similar fabrication technology.

2013 Three billion qubits were held in a state of superposition for 39 minutes, exceeding the previous record of 2 seconds (2012).

2014 Leaked documents show that the US National Security Agency is interested in quantum computing for cryptography purposes. Quantum teleportation demonstrated over 3 metres. This is necessary for a quantum-based Internet to make it secure and fast. The largest number ever factored on a quantum computer was achieved, 56,153 exceeding the previous record of 143. University of New South Wales researchers embedded qubits in silicon to protect them and give them longer decoherence times.

2015 D-Wave Systems announce a 1,000 qubit system. University of New South Wales researchers build the world's first quantum logic gate in silicon.



The Titan supercomputer at the Oak Ridge National Laboratory, Tennessee, USA is the most powerful classical computer in the Western world and the most powerful supercomputer that is freely accessible. It uses 18,688 AMD Opteron 6274 16-core CPUs and the same number of Nvidia Tesla K20X GPUs or graphics processing units. It has a benchmark of 17.59 petaFLOPs (where peta is 10^{15} or 1,000,000,000,000,000 and a FLOP is one floating point operation per second). The computer runs the Cray Linux Environment and it consumes 8.2MW. There is a more powerful Tianhe-2 supercomputer in China; however it uses US-made CPUs, is not freely accessible and has been criticised for its difficulty of use. Quantum computers will not replace computers such as these but will supplement them.

in a state of superposition. If a measurement is made (thus destroying superposition) on one particle and it is found to have an up spin, for example, the other particle will automatically acquire a down spin as the total spin of the pair must be zero (an up spin plus a down spin).

The particle that is not measured changes its quantum state as if to "know" a measurement has been made on its partner. This happens no matter by what distance the particles are separated and would happen even if the particles were at opposite ends of the universe.

Furthermore, the change is instantaneous, not propagated at the speed of light as might be expected. The information travels at an infinite speed, although it cannot be used for faster-than-light communication. Einstein called this phenomenon "spooky action at a distance" and felt it meant that the description of reality by quantum mechanics was incomplete.

Bits and Qubits

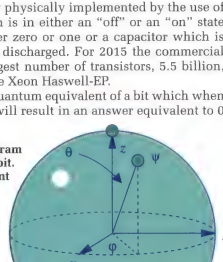
The basic unit of information in a conventional computer is the bit which can have a value of either zero or one. It is typically physically implemented by the use of a transistor which is in either an "off" or an "on" state representing either zero or one or a capacitor which is either charged or discharged. For 2015 the commercial CPU with the largest number of transistors, 5.5 billion, was Intel's 18-core Xeon Haswell-EP.

A qubit is the quantum equivalent of a bit which when read (measured) will result in an answer equivalent to 0 or 1. Due to the principle of quantum superposition as explained above, the qubit can have a combination of these values at the same time whereas a conventional bit must be either zero or one but not both at any given time.

A qubit can be physically represented by the states of various quantum particles such as the spin of electrons (which are either up or down) or other quantum-dominated systems (see below).

A qubit is regarded as the superposition of two basis states which are denoted mathematically as |0> and |1> (spoken as ket 0 or ket 1) and are equivalent to 0 or 1 in classical computing. While an ordinary bit in classical computing can be represented in a diagram by either a simple 0 or 1 a qubit is a bit more complicated and is represented by a Bloch Sphere as shown.

On the Bloch spere, the "north" and "south" poles represent the basis states of |0> and |1> which physically might



Bloch sphere diagram representing a qubit. x, y and z represent the axes of the sphere, the north and south poles represent the basis states and the ψ represents the superposition of |0> and |1>. Φ and θ represent angles. Image credit: Glosser.ca [CC BY-SA 3.0]

Simulating a Quantum Computer without yet having one!

There are a lot of problems to solve with quantum computers but algorithms and computer code still need to be developed to solve these problems.

Microsoft have developed a software simulation tool called LIQUi|> or Language-Integrated Quantum Operations (the symbols at the end a notation used in quantum computing) that transforms a higher level computer language such as F# that is coded to represent a quantum operation into one specific to low level operations in quantum computers.

It allows researchers to write and develop quantum code on conventional computers in the absence of access to full scale quantum computers that Microsoft judges to be 10-20 years away, notwithstanding the developments described here. If you are interested in looking at this it can be downloaded free from https://github.com/msr-quarc/liquid

That version allows for the simulation of up to 23 qubits. Among specific algorithms that can be simulated and which are included as examples are: simple quantum teleportation, Shor's factoring algorithm, quantum chemistry, computing the ground state energy of a molecule, quantum error correction, quantum associative memory and quantum linear algebra.

represent spin up or spin down states. The superposition of these states – the qubit - is represented by some point anywhere on the sphere.

When the state of a qubit is measured there is a loss of superposition and thus the system can no longer be in two states simultaneously due to quantum decoherence. The result is |0> or |1>, equivalent to 0 or 1 in classical computing.

When multiple qubits exists in a system they can possess the property of entanglement, mentioned above. This means that, for example, a pair of entangled qubits will maintain a relationship with each other so if one is measured (thus causing quantum decoherence) and found to have a spin up state, the other will automatically have a down spin.

Entanglement is one method by which multiple qubits can be made to "work together" and thus solve more complex problems.

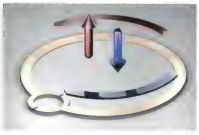
Information representation in bits and qubits

Consider the information that can be represented in a 2-bit system. Two bits can be represented as either 00, 10, 01 or 11. Two bits can therefore represent only one of four different values and to use all four values in some given computation the computer would have to execute at least four cycles so that each value could be loaded and then used in a calculation.

On the other hand, a 2-qubit quantum computer can contain and utilise for a calculation all those four values (above) simultaneously so only one computer cycle is necessary to operate on all four items of data.

In other words, two bits contain information about only one value and two qubits contain information about four values. In fact, quantum computers scale the information that can be contained in the qubits exponentially according to 2^n where n is the number of qubits.

A 4-qubit computer could, for example, simultaneously hold sixteen values (2^4), ie, 0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111, 1000, 1001, 1010, 1011, 1100, 1101, 1110 and 1111. In contrast, a conventional 4-bit computer could store only one of those sixteen values and would have to repeat an operation 16 times to do the same computation as the quantum computer could do just once.



SQUID as used for the qubit in the D-Wave quantum computer. The horizontal arrows represent the possible directions of current and the vertical arrows represent the two possible spin states, up or down corresponding to zero or one.

A multiprocessor classical computer increases its power directly in proportion to the number of processors it possesses. The ability for data representation to scale exponentially in a quantum computer compared to a classical computer and subsequent processing of that data is a key to its theoretical power, providing that can be implemented in a practical manner. In other words a quantum computer is not simply the same as a classical parallel processing computer.

What can be used as a qubit?

Almost any system that displays quantum mechanical phenomena can be used as the basis of a qubit as long it is capable of possessing two different quantum mechanical states, such as spin up or spin down.

Any real quantum computer might have a combination of different two state systems just as a classical computer uses the state of a transistor in a CPU, capacitors in RAM, the pit or absence thereof in optical media such as a DVD or the state of a magnetic domain on a hard disk.

Systems proposed include but are not limited to: electrons (spin up or down), light (amplitude or phase "squeezed"), Josephson junction and SQUIDs (direction of current), photon (vertically or horizontally polarised), atomic nucleus (spin up or down), optical lattice (spin up or down), quantum dot (spin up or down), graphene quantum dot (spin up or down), trapped ion (state of ions), nuclear magnetic resonance of liquid molecules (nuclear spin state) and diamonds (nuclear spin of atomic vacancies). Note:

What would program code for a Quantum Computer look like?

Anyone who has learned to program has probably started with a simple program such as the classic one that prints "Hello world". What would a very simple program on a quantum computer look like?

No one yet knows how quantum computers and their programming languages will evolve but it might look like the following.

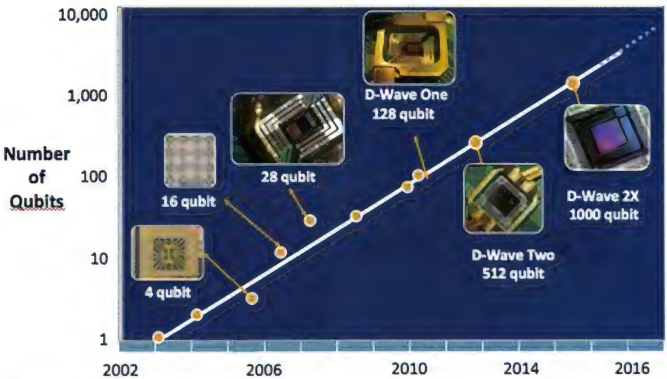
Consider a quantum computer language with just four instructions N (create qubit), E (entangle qubit), M (measure qubit) and X (execute operation). This program creates an ancilla, a special bit used for quantum error correction, entangles it with the input qubit, measures the input qubit and conditionally performs an operation on the ancilla.

After the operation, qubit 2 contains the state of qubit 1 after a Hadamard transformation has been performed. A Hadamard transformation is a one qubit rotation whereby two qubit states are mapped onto two superposition states with the same computational state as the original qubits (more generally it is a class of Fourier transforms).

Note that this is very low level programming, equivalent to assembly language in a conventional computer and coding would not normally be done at such a low level – much higher level programming languages would be used.

```
N 2     # create a new quantum bit and identify it as '2'
E 1 2   # entangle qubits '1' and '2', qubit 1 already exists
          and is considered input
M 1 0   # measure qubit '1' with an angle of zero
          (angle can be anything in [0,2pi)
        # qubit '1' is destroyed and the result is either
          True or False
        # operations beyond this point can be dependent
          on the signal of '1'
X 2 1   # if the signal of qubit '1' is True, execute the
          Pauli-X operation on qubit '2'
```

Reference: http://cstheory.stackexchange.com/questions/9381/what-would-a-very-simple-quantum-program-look-like



This graph shows "Rose's Law" demonstrating the steady increase in the number of qubits in the D-Wave quantum computer which is analogous to Moore's Law with the number of transistors in a classical computer,

SQUID is a superconducting quantum interference device.

Note that a qubit does not have to be physically small, although that is desirable so many qubits can be placed on one chip.

Basic elements of a quantum computer

A practical quantum computer must have certain basic requirements (DiVincenzo's criteria) some of which also differ from a conventional computer as explained below.

1) It must be scalable to enable a reasonable number of qubits just as a conventional computer must have a reasonable number of bits for efficient operation.
2) The qubits must be able to be set to a common initial state such as all zeros, just as are the bits in a conventional computer.
3) The state of the computer must be controllable using universal gates such as quantum logic gates. They are analogous to the logic gates in conventional digital computer circuits (but unlike in a conventional computer they are reversible).
4) To enable logic operations to be performed by the logic gates the decoherence times of the qubits must be long enough for the gate operation to complete. Decoherence can be suppressed by error correction techniques and fault tolerant computation. The logic state of a conventional digital circuit will remain indefinitely but qubits are inherently unstable and will eventually revert to an alternative state. A stability time of somewhere between nanoseconds and seconds is required.
5) There has to be a means to read the quantum state of the processor. In quantum mechanics, the very act of taking a reading or measurement will alter the state of the system. Conventional digital circuits can be read without altering the state of the system.

Quantum decoherence

As mentioned above, quantum decoherence can happen due to making a measurement or reading but it can also happen for unwanted reasons and this represents one of the greatest challenges of quantum computing.

A quantum system can decohere due to thermal vibrations in the atomic lattice (if a crystal-based system is used) or other subatomic or macro scale phenomena. One partial solution is to cool the quantum processor to extremely low temperatures in order to reduce thermal vibrations.

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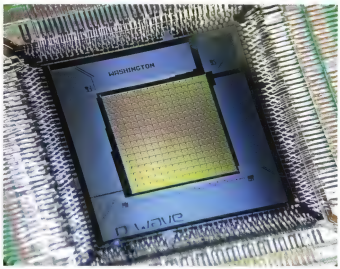

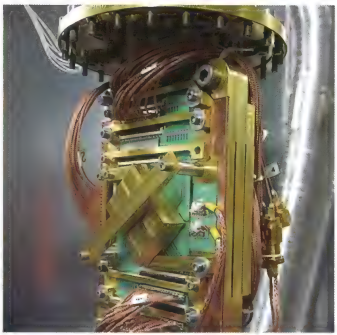

(Above): closeup of the D-Wave 1000 qubit quantum processor.
(Right): D-Wave processor package mounted on dilution refrigerator to keep it at a temperature close to absolute zero.

Temperatures as low as 20mK or twenty thousandths of a degree above absolute zero are required. This corresponds to -273.15° Celsius and is much colder than anywhere in the universe, which doesn't get much colder than about 3° above absolute zero.

Cooling won't necessarily remove all instances of decoherence and it is necessary to use quantum error correction to detect and reduce errors however this comes at the cost of the requirement for many more qubits in the system.

Conventional computers, it should be noted, also use extensive error correction to ensure they operate correctly and in very early digital computers it was necessary to run a program several times to ensure the same result was obtained each time and if it was, confidence could be had in the result!

Operation of a Quantum Computer

To operate a quantum computer the qubits are first set to an initial state representing the problem and then those qubits are manipulated using quantum logic gates which are operated in a sequence according to a quantum algorithm.

Quantum logic gates are like logic gates in classical computers (although their operation is reversible). A quantum algorithm consists of the step-by-step instructions for solving the problem but is specifically designed to utilise features of the quantum computer such as superposition and entanglement. Algorithms from classical computers can also be implemented on a quantum computer.

Two widely known quantum algorithms are Shor's algorithm for factoring and Grover's algorithm for searching unstructured databases.

Once a quantum computer has finished running an algorithm, a measurement of the qubits is made which collapses the qubits into their basis states, representing a zero or one to yield the result.

Some quantum algorithms give the correct answer only with a certain probability and may give a different result each time the algorithm is run! This is the case with some algorithms run on the D-Wave computer discussed next. When these algorithms are run multiple times the most common result is likely to be the correct one.

The commercial D-Wave Quantum Computer

The only company making quantum computers on a commercial basis is D-Wave Systems (www.dwavesys.com), a Canadian company founded in 1999.

D-Wave's computers run a very specialised type of process called quantum annealing which is used for solving problems involving optimisation where a huge number of options are reduced to the best choice.

One way to think of these problems is to think of a metaphor involving a vast landscape with many hills and valleys. The object is to find the lowest valley (the best choice) and the way to do it is either to

1) survey the whole landscape by walking up and down the hills looking for the lowest valley as a conventional computer would do or

2) use the quantum computer to effectively tunnel through the hills to quickly find the lowest point.

The basis of the qubit in the D-Wave computers is a SQUID or Superconducting QUantum Interference Device. The device is made of a ring of superconducting niobium and a junction. Current within the ring can flow in one direction or the other, resulting in magnetic spin states which are either up or down although before measurement the device is in a superposition of both states, effectively meaning that the current flows in both directions at once.

The D-Wave computer quantum processor must be kept at a temperature close to absolute zero to minimise quantum decoherence and also to ensure that the SQUID devices can operate in their superconducting state. The large size of the computer is primarily due to the cooling equipment.

In the quantum annealing process, the algorithm used to run calculations tries to predict what states the qubits will be in when the temperature of the SQUIDs is increased, thus finding the solution or set of solutions for the lowest point in the valley in the landscape metaphor described above.

As mentioned previously, this computer does not necessarily give the

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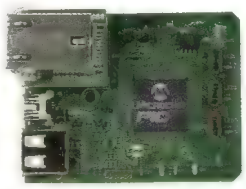

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same answer to a problem if run a second time however the more answers it repeatedly gives which are the same, the greater the confidence one has in the result.

D-Wave sees this as an advantage as it assists in determining the confidence the computer has in the result of complex computer-based decisions in machine learning applications.

The D-Wave computer is in use by Google, NASA, Lockheed Martin and others.

Google hopes to use the computer for image and news classification, spoken word recognition, machine learning and understanding natural language and is doing research into other possible uses.

The D-Wave computer has been criticised because it is not a "universal quantum computer" meaning that it cannot run any type of calculation but is limited to just "combinatorial optimisation problems" and it thus cannot run Shor's algorithm, for example.

Another criticism relates to whether it truly is a quantum computer and-whether it uses entangled states.

The reality is that no one fully understands how it works in all aspects, not even the designers, although it is now generally agreed that it is indeed a real quantum computer.

Other issues relate to questions of how to benchmark the speed of such a computer and compare it to classical computers.

Conclusions

The dream of quantum computing has been around for a while and now there is one type of specialised quantum computer in commercial production with major research in other areas of quantum computing, with Australia being a key player.

Quantum computers will not replace classical computers but will supplement them by solving specialised types of problems for which they are suited.

It is also important to distinguish hyperbole from reality.

Most likely quantum computers will be introduced slowly, at first solving a limited number of problems and then, perhaps, the market will expand as they solve problems with widespread demand, such as understanding and interpreting spoken language, recognising objects or even artificial intelligence. SC

Making single atom qubits, atomic wires

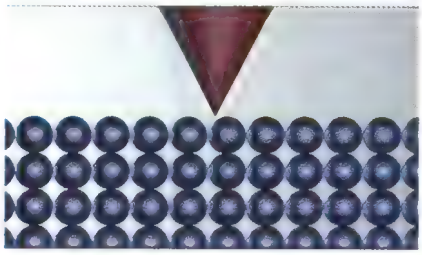
Australia is a world leader in aspects of quantum computing.

The Centre of Quantum Computation and Communication Technology (www.cqc2t.org/) is a collaboration between The University of NSW, The University of Melbourne, Australian National University, Griffith University, The University of Queensland and The University of Sydney.

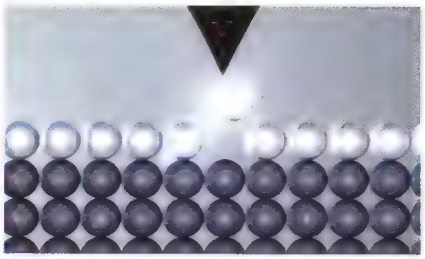
It is undertaking work involving a diverse area of quantum communication and quantum computing. One particular project is the Precision Qubit Program.

This program involves making qubits using single atoms and aims to "position, control and read out the electron spin on a single (phosphorus) atom in silicon which acts as a quantum bit or qubit". Single electron transistors and microwave strip lines are used to both read and manipulate the electron spin on a single phosphorus atom embedded in a crystal of silicon.

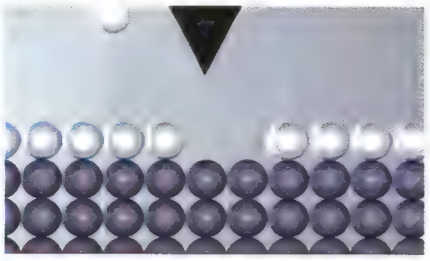
The ability to create a single atom



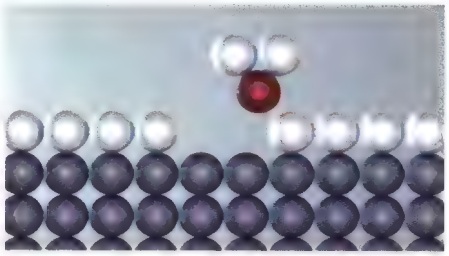
(1) To make an image of an atomic structure the probe of a scanning tunnelling microscope (STM) is moved along the surface of a silicon crystal and an image of the surface is obtained by measuring a current flowing between the crystal and the tip which varies according to the position on the crystal surface. An STM can also be used to manipulate single atoms on the crystal surface. It is important to map the crystal surface so the exact location of the qubit is known.



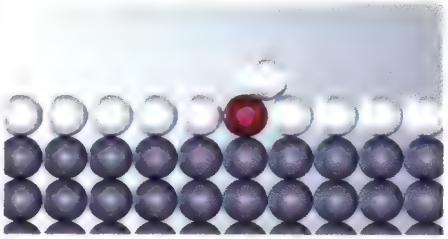
(2) A layer of hydrogen atoms (light colour) is laid down on the silicon surface to create the desired types of surface chemical bonds. A pulse of current is then applied to the STM probe which removes one hydrogen atom.



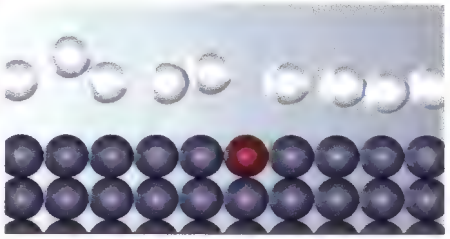
(3) A second pulse of current is then applied to the STM tip to remove a second hydrogen atom.



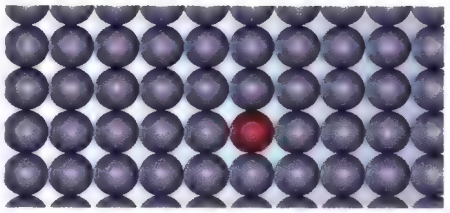
(4) Phosphine gas, consisting of phosphorus (red) and hydrogen, is introduced and the molecule of gas settles in the place where the two hydrogen atoms were removed.



(5) The phosphorus atom of the gas molecule now lies on the surface of the silicon crystal.



(6) The hydrogen atoms are removed.

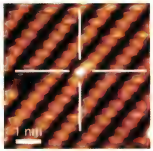


(7) More silicon atoms are added to the surface, embedding the phosphorus atom deep in the atomic structure where it is not affected by undesired interference from the crystal surface. (Diagrams captured from https://youtu.be/0dXNmbiGPS4)

and the single atom transistor

qubit and support structures such as nano-wires to access the qubit is a remarkable achievement and only possible due to the recent development of techniques to reproducibly manipulate single atoms and also to know exactly where those single atoms are located within the crystal lattice.

The illustrations in the numbered images in the box show how a single atom of phosphorus is embedded into a specific location within a silicon crystal.



Actual STM image of a phosphorus atom (centre) located on the surface of a silicon crystal at step 6. The scale bar represents one nanometre, one millionth of a millimetre.

The ability to accurately place a single atom at a precise location plus the ability to make an atomic scale wire allow the fabrication of a single atom transistor. Such a transistor can be used as a qubit or as a component of a classical computer.

While making such a device is a fantastic start, practical computers need large numbers of devices on the one chip. Also, according to Moore's Law for classical computing which says that the number of transistors on a chip doubles every 12 to 18 months, the size will need to reach the atomic scale by 2020 if that rate of advancement is to be maintained. Obviously beyond the point of a single atom transistor, no further size reduction is possible.

STM image of single atom transistor. The single phosphorous atom is at the centre and the atomic scale wires are shown in pink.

Dr Matthew House with Honours student Kirsti Date studying deterministic placement of single donors in silicon at the Atomic Fabrication Facility at the University of New South Wales.

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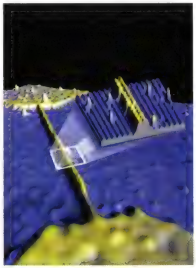

An atomic scale wire just one atom tall and four atoms wide. This is the type of wire that may be used to connect to single atom qubits.

It was made by using an STM to create a channel in the silicon and then exposing the area to phosphine gas to make a line of phosphorus atoms and then depositing silicon atoms on top of the phosphorus atoms (similar to with the numbered images). The phosphorus atoms, which were placed at a spacing of less than one nanometer, doped the region around their vicinity causing it to become conductive and act as a wire.

A similar conductivity and current carrying capability as copper was achieved. This particular work also proved that Ohm's law operates at the atomic scale which was not an expected result as quantum effects were though to dominate at this size scale. On the other hand, a concern that has been raised from the knowledge that Ohm's law still works at this scale is that non-quantum affects may dominate making a qubit difficult to implement. Another important outcome of this work relates to conventional silicon chip fabrication.

Companies such as Intel have become increasingly worried that the feature size on microprocessors is becoming so small that quantum effects will soon start to dominate and no further miniaturisation can occur.

Already transistor gate sizes are at 22nm which is about 100 times the spacing of silicon atoms. This work suggests that miniaturisation can continue for some time and down to much smaller feature sizes.

Image Courtesy of the Centre for Quantum Computation & Communication Technology.

Macroscopic quantum entanglement achieved at room temperature

As we went to press, this article by Colin Jeffery appeared in the February 2 issue of "Gizmag" (www.gizmag.com) and follows several other articles on Quantum Computing, including one on the role UNSW scientists are playing in this exciting field.

The researchers believe that the advance could lead to entanglement-enhanced magnetic resonance imaging probes (Credit: Awschalom Group/University of Chicago)

In quantum physics, the creation of a state of entanglement in particles any larger and more complex than photons usually requires temperatures close to absolute zero and the application of enormously powerful magnetic fields.

Scientists working at the University of Chicago (UChicago) and the Argonne National Laboratory claim to have created this entangled state at room temperature on a semiconductor chip, using atomic nuclei and the application of relatively weak magnetic fields.

When two particles, such as photons, are entangled – that is, when they interact physically and are then forcibly separated – the spin direction imparted to each is directly opposite to the other.

However, when one of the entangled particles has its spin direction measured, the other particle will immediately display the reverse spin direction, no matter how great a distance they are apart.

This is the "spooky action at a distance" phenomenon (as Albert Einstein put it) that has already seen the rise of applications once considered science fiction, such as ultra-safe cryptography and a new realm of quantum computing.

Ordinarily, quantum entanglement is a rarely observed occurrence in the natural world, as particles coupled in this way first need to be in a highly-ordered state before they can be entangled. In essence, this is because thermodynamic entropy dictates that a general chaos of particles is the standard state of things at the atomic level and makes such alignments exceedingly rare.

Going up a scale to the macro level and the sheer number of particles involved makes entanglement an exceptionally difficult state to achieve.

In standard sub-atomic quantum entanglement experiments using photons, for example, very high energy photons are generated using a laser and then directed through a nonlinear crystal.

The majority of the photons will pass straight through unimpeded, however some will undergo a process known as spontaneous parametric down-conversion (SPDC) where, simply stated, a single high-energy photon will split into two lower-energy photons.

As a result of this SPDC, the two photons will have been created entangled, with opposing spin polarisations, because they both were spawned from a single particle.

At a macroscopic level, however, things aren't quite as simple, and particles such as atoms in solids and liquids are particularly difficult to wrangle into a quantum state.

This is because the difficulties of overcoming quantum decoherence (where interfering wave functions from surrounding atoms cause the collapse of quantum states) in entangling particles normally means that ultra-low temperatures (around -270°C) and strong magnetic fields (about 1,000 times greater than that of an average refrigerator magnet) are required.

This is to keep atomic movement close to zero and contain the entangled particles, both of which reduce the likelihood of decoherence.

Given that a practical application of entanglement of macroscopic particles is to allow quantum electronic devices to operate in real world situations and at ambient temperatures, the researchers sought a different approach to this problem.

Using an infrared laser, they coaxed into order (known in scientific circles as "preferentially aligned") the magnetic states of many thousands of electrons and nuclei and then proceeded to entangle them by bombarding them with short electromagnetic pulses, just like those used in standard magnetic resonance imaging (MRI).

As a result, many entangled pairs of electrons and nuclei were created in an area equal to the size and volume of a red blood cell on a Silicon Carbide (SiC) semiconductor.

See the full article at www.gizmag.com/quantum-entanglement-nuclei-university-chicago-argonne/40884/

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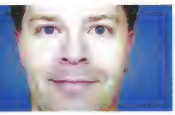

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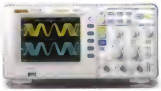

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By Geoff Graham

Ultrasonic Garage Parking Assistant

This Garage Parking Assistant will display the distance from the back wall of your garage or carport to your car's bumper bar, in large digits and with a colour coded background: green for go, yellow for slow down and red for stop. It makes positioning the car a breeze as you will always know just how many centimetres you are from the wall or an ideal stopping point.

THIS PROJECT is based on the Micromite LCD BackPack described in last month's SILICON CHIP. The BackPack is a low-cost, touch-sensitive LCD panel coupled with an even lower cost microcontroller programmed in BASIC. Turning this into our Digital Garage Parking Assistant only requires the addition of an ultrasonic distance sensor and a suitable BASIC program.

As you drive the car into the garage the display will light up, with the distance in centimetres displayed on a green background. As you come closer, the background changes to yellow and then finally to red. During this time, the display will tell you the exact distance to the wall or an ideal stopping point in large 25mm-high digits. Finally, after the vehicle has been stationary for a little while, the display blanks, ready for the next time you park the car.

By making some small changes to the software program, you could use the same design for other applications where you need to know the distance to an object. For example, with a simple modification, the unit could display the water level in a rainwater tank. Based on the dimensions of the tank, it could also calculate and display the content in litres, with the background colours serving as a warning when the

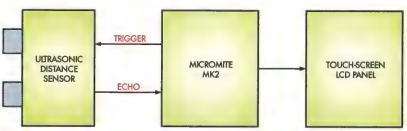
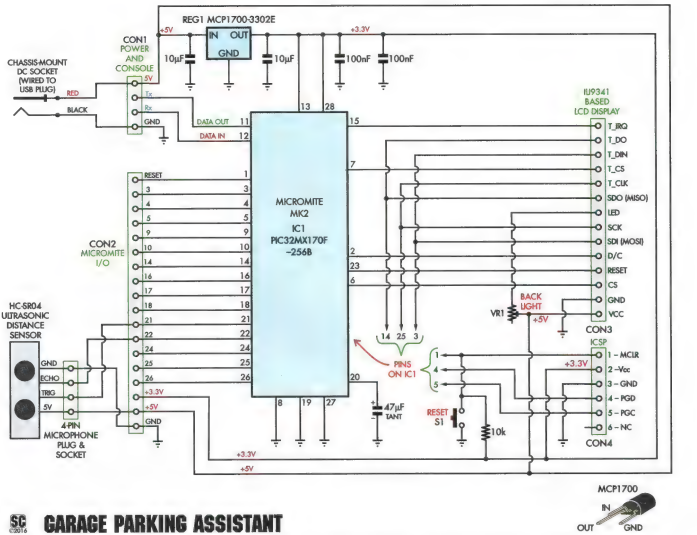


Fig 1: this block diagram shows the main components in the Garage Parking Assistant. The Micromite is in control: using the trigger line, it signals the ultrasonic distance sensor to transmit an ultrasonic sound pulse then measures the round trip time on the echo line. The result is converted to centimetres and displayed on the touch-screen LCD panel.



GARAGE PARKING ASSISTANT

Fig.2: the circuit is based on a Micromite LCD Backpack, a touch-screen LCD and an ultrasonic distance sensor. IC1 does most of the work, while REG1 is a 3.3V voltage regulator. The ultrasonic distance sensor is triggered by pin 21 of the Micromite and the subsequent echo signal is then fed to pin 22. A 5V USB charger powers the circuit.

water has dropped to a low level.

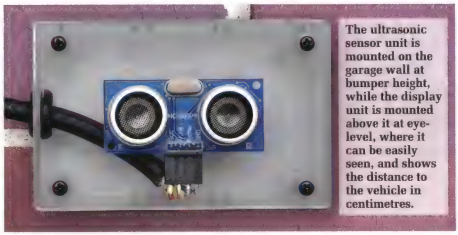
The program running on the Digital Garage Parking Assistant is written in BASIC. This is an easy-to-learn programming language and the program is stored in plain text. And because the Micromite has its own program editor, you can connect it to a laptop and easily change the program to suit your preferences, even when it is attached to the garage wall.

You might, for example, prefer the distance to be displayed in old-fashioned inches. That would require the modification of just one line in the program and could be done in minutes.

How it works

Fig.1 shows the block diagram of the Garage Parking Assistant, while Fig.2 shows the full circuit (including the LCD BackPack). The key components are an ultrasonic distance sensor, Micromite microcontroller IC1 and the LCD panel. The Micromite is completely in control; it uses the ultrasonic transducer to measure the distance and then displays the result on the LCD panel.

The distance sensor emits an ultrasonic pulse and then listens for the re-



The ultrasonic sensor unit is mounted on the garage wall at bumper height, while the display unit is mounted above it at eye-level, where it can be easily seen, and shows the distance to the vehicle in centimetres.

The background colours on the LCD provide a simple visual warning to the driver – green to continue, yellow to slow down and red to stop. In addition, the LCD shows the distance readout in centimetres. You can change the thresholds used for the three colours via the touch-screen and the various options menus.

turn echo, under the control of the Micromite. The microcontroller starts the measurement cycle by triggering the ultrasonic signal with a short positive pulse on the trigger line of the sensor. The sensor then raises the echo line to a logic high level to acknowledge that it has sent the ultrasonic pulse and then drops it low again when the echo is received.

The time that the echo pin is held high by the sensor represents the round trip time for the ultrasonic pulse to leave the sensor, reach the distant object and bounce back to the sensor. The microcontroller must accurately measure this time and then calculate the distance to the target.

In a normal microcontroller, this operation can be complex but on the Micromite it's easy. The BASIC program just needs to use the DISTANCE() function which will automatically generate the trigger pulse and calculate the distance to the target. The result is returned as a floating point number representing the distance in centimetres to one decimal place.

For example, if you had an ultrasonic transducer connected to pins 21 (trigger) and 22 (echo), the following command would display the distance (in centimetres) to the target:

```
PRINT DISTANCE(21, 22)
```

The output from running the above command would be a number. For example, 26.1 would mean that the distance is 26.1 centimetres.

The sensor will work with a target that ranges from 30mm to 3m. The precision will vary depending on several factors, such as the reflectivity of the object and the air temperature, but is generally accurate to within 10mm. This range and accuracy is more than adequate for our Garage Parking Assistant.

The ultrasonic sensor goes by the part number HC-SR04 and can be found on eBay or purchased from the Silicon Chip Online Shop. Compatible sensors are the SRF05, SRF06, Parallax PING and the DYP-ME007 (which is waterproof and therefore good for locations that are exposed to the weather). All of these work exactly the same as the HC-SR04.

The ultrasonic distance sensor used in the Garage Parking Assistant. The righthand transducer is used to transmit the sound pulse and the lefthand transducer receives the reflected signal. The sensor will work with targets ranging from 30mm to 3m and is generally accurate to within a centimetre.

The Micromite

The Micromite has been described many times before in Silicon Chip and has evolved into a powerful but inexpensive controller. The IC used here is a 28-pin dual-in-line (DIL) package which can be plugged into an IC socket and is programmed using a version of BASIC called MMBasic.

BASIC stands for "Beginner's All-purpose Symbolic Instruction Code". Originally designed as an interactive teaching language by Dartmouth College in the USA in 1963, it subsequently became widely used on early personal computers. Because of its simplicity, BASIC is often used for teaching the fundamental concepts of programming.

The program for the Garage Parking Assistant is written in BASIC and because of this, it can be easily modified to suit your preferences. For example, if you do not like the colours you can change them to suit yourself.

The Micromite is coupled with a low-cost touch-screen LCD panel which can display 320 by 240 pixels in any one of 65,535 colours. We chose the larger 2.8-inch version for our prototype because the displayed digits are easier to see from the driver's seat; they are just over 25.4mm (1-inch) high. If you already have the 2.4-inch LCD, this could be used instead. Its mounting arrangement (on the lid of the case) will be slightly different, however.

The Garage Parking Assistant uses the touch input to set its various options. All you need do is tap the screen and the main options menu appears.

Touch support is another area where the BASIC language makes programming easy. The TOUCH() function will return the X and Y coordinates of the touched location in pixels. Using this and a selection of drawing commands, it is possible to create touch sensitive buttons and other screen objects that make sense to the casual user.

Options

The photo at top-right on the facing page shows the main options menu that appears when the screen is touched. In particular, it shows the timeout, offset and thresholds for the background colours.

The timeout is simply the length of time after the car has stopped moving before the display is blanked. By contrast, the offset is the distance from the sensor at which the displayed dis-

tance will be shown as zero. It is useful if the sensor is mounted on a wall but the car must stop before the wall is reached, perhaps because of some other obstruction.

For example, if the offset is set at 10cm, the display will read zero when the distance between the car's bumper bar and the sensor has been reduced to 10cm.

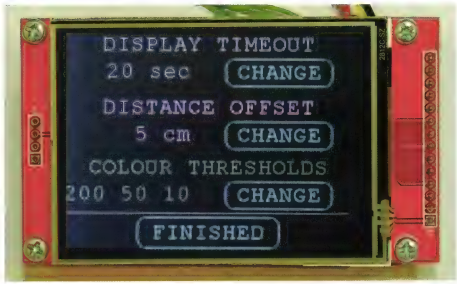
Either of these two settings can be changed by touching the CHANGE button. In this case, a virtual on-screen keypad will be displayed which allows the required number to be keyed in. An example of this is shown in the photo below left. The keypad includes the ability to delete the previously entered digit (the DEL key) or cancel the entry and return to the menu (the CAN key). Pressing the ENT key will store the keyed-in number and return to the previous menu.

The third entry on the main options screen shows the thresholds for the colour changes. Pressing the change button for this entry will open up a new menu as shown in the photo below right. **By default the threshold for green is 200cm, for yellow it is 50cm and for red it is 10cm.**

Initially, as the vehicle approaches, the LCD will be blank but when the vehicle's distance reaches the green threshold, the display will light and show the distance with a green background. Similarly, when the yellow threshold is reached, the background will change to yellow and so on.

These colour changes provide a simple visual warning for the driver – yellow means slow down and red means stop immediately. **You can easily change these thresholds by touching the CHANGE button and keying in the new number.**

The FINISHED button will save the options and return to the previous screen. All options are saved in non-volatile memory, so they will be retained even if the power is removed.



Touching the screen on the Garage Parking Assistant displays the options settings. This photo shows the main menu, which displays the current settings for the timeout, the offset and the thresholds. Touching the CHANGE button for a particular parameter brings up a virtual keypad (see photo below) so that the setting can be changed.

Building the LCD Backpack

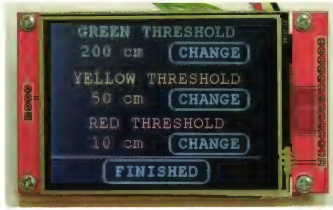
The first step in the construction is to build the Micromite LCD BackPack and test it to make sure that it's working correctly. This was described in last month's issue of SILICON CHIP so we won't go into too much detail here. Besides, with the silk screening on the PCB, it's obvious where the parts go and it should take less than half an hour to build.

Loading the firmware and the BASIC program is essentially a 3-step process. First, the blank PIC32 microcontroller must be programmed with the Micromite firmware which includes the BASIC interpreter (MMBasic). That done, the interpreter needs to be configured to suit the LCD panel. And finally, the BASIC program that drives the ultrasonic sensor and the display needs to be loaded.

You have a few choices when it comes to this process:

Option 1: the first option is to download the file "ParkingAssistFull.hex" from the SILICON CHIP website and program the PIC32 yourself. This file has the Micromite firmware, the settings for the LCD panel and the BASIC program

This is a typical virtual keypad which allows the user to enter a new number. It includes the ability to delete the previously entered digit (the DEL key) or cancel the entry and return to the menu (the CAN key). Pressing ENT will store the number and return to the previous menu.



The thresholds for bringing up different background colours can be changed using this menu. The Finished button saves the options and return to the previous screen. All options are saved in non-volatile memory so they will be retained even if the power is removed.

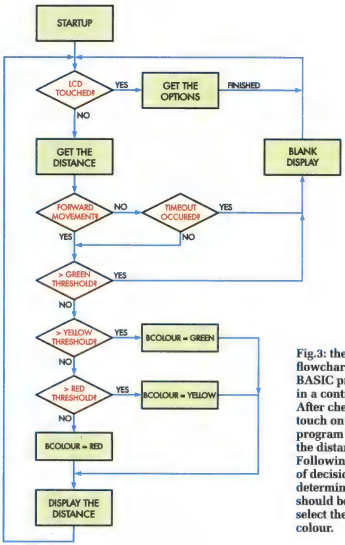


Fig.3: the software flowchart diagram. The BASIC program runs in a continuous loop. After checking for a touch on the screen the program then measures the distance to the car. Following this, a series of decisions are made to determine if the display should be blanked or to select the background colour.

all combined into one "package". It must be programmed into the PIC32 microcontroller using a programmer such as the PICkit 3.

Using this firmware is quite convenient because this single operation combines all three steps and sets up the chip so that it's ready to do the job.

Option 2: the second (and easiest) option is to purchase the PIC32 microcontroller pre-programmed with the combined firmware file from the SILICON CHIP Online Shop. Then, all you need to do is plug the chip into its socket and you are ready to go.

Option 3: the third option is to go through all three steps individually. Step 1 is to download the file "Micromite_V5.1.hex" from the SILICON CHIP website and program it into the PIC32 microcontroller using a PICkit 3. Step 2 is to connect a USB-to-serial converter to the Micromite's console and configure the chip to work with the LCD and touch. And finally, step 3 involves loading the BASIC program "ParkingAssist.bas" (again available from the SILICON CHIP website). This can be loaded using either the XMODEM protocol or using the AUTOSAVE command.

The above process was described in detail in last month's article on the Micromite LCD Backpack and isn't hard to do. When you have run through all three steps, the result will be exactly the same as if you had loaded the combined firmware containing the interpreter, the settings and the BASIC program (or if you purchased a pre-programmed chip).

The only issue that you need to be aware of is that the touch calibration in the combined firmware was done with a reasonably standard LCD panel but yours might require re-calibration if it is significantly different from the "standard" that we used. If you discover that the touch calibration is inaccurate, this can be corrected by connecting a USB-to-serial converter to the console, halting the program with CTRL-C and re-running the calibration. The calibration procedure was also described in detail last month.

Note that if you already have a working Micromite LCD BackPack, then it will only be necessary to load ParkingAssist.bas into the PIC32 micro. Alternatively, you can choose to reprogram the chip with the combined software (ie, ParkingAssistFull.hex).

Program operation

If you wish to modify the BASIC program, you need to have some idea of how it works. Fig.3 provides a high-level flow diagram of its operation.

As shown, the program runs in a continuous loop. First, it checks if the LCD is being touched and if it is, branches to a subroutine which will display the menus and the options.

The program then retrieves the distance from the ultrasonic sensor which is averaged over five successive readings to reduce noise. It then checks for forward movement and if there is none it checks for a timeout. This is the time that the display remains on after the vehicle has stopped moving. If the vehicle is stationary, a counter will increment every second and the program will blank the display when the counter reaches the timeout setting.

The program next checks the vehicle's distance and compares it to the green threshold. If it is greater than this threshold, it blanks the display and returns to the start of the loop for another "go around". If the distance is less than the green threshold, the program checks the other thresholds to determine the colour to be used, ie, green, yellow or red.

Finally, the program displays the distance in centimetres with the specified coloured background. It then loops around to get another distance reading and repeat the process.

If you are going to modify the program there is one feature that you need to be aware of. In the main program loop, the watchdog timer is set to one second. This timer is used to automatically restart the program if an error occurs.

In operation, the timer must be constantly reset to one second to prevent a restart under normal operation. This means that you must make sure that the

program can execute the loop in less than one second to avoid an automatic restart of the Micromite.

The watchdog timer is also used when the program detects a touch on the screen and branches to the menus where the options are set. In this case, the timeout is set to 10 minutes every time a button is touched. This was included in the program so that the Micromite will automatically restart and return to normal operation after 10 minutes of inactivity within any menu – handy if you have been called away while fiddling with the settings and forget to return.

Building it

The first job in the assembly is to build and calibrate the Micromite LCD BackPack, as detailed in the February 2016 issue of SILICON CHIP. It's then just a matter of mounting the LCD BackPack assembly and the ultrasonic sensor assembly in separate enclosures and connecting them together.

As shown in the photos, the Micromite LCD Backpack is mounted inside a UB3 ABS box, while the ultrasonic sensor goes in a smaller UB5 box. A 4-core cable joins the two units and allows the sensor to be mounted at bumper bar height, while the Micromite LCD BackPack can be mounted above it at eye height.

In each case, the lid supplied with the box is discarded and replaced with a laser-cut clear acrylic panel (available from the SILICON CHIP Online Shop; see parts list). The panel for the BackPack assembly comes with all the mounting holes plus a precision cut-out for the touch-screen LCD, while the panel (or lid) for the UB5 box comes with corner mounting holes plus neat circular cut-outs for the two ultrasonic transducers.

Fig.4 shows how the LCD BackPack assembly is mounted. First, the touch-screen LCD is attached to the acrylic lid at each corner using an M3 x 10mm machine screw, two stacked M3 washers and an M3 x 12mm tapped spacer. This arrangement ensures that the LCD sits flush with the clear acrylic lid.

Note that the LCD itself is offset to the left on its PCB, so be sure to fit the module the right way around, so that the viewing area is centred horizontally on the acrylic panel. Once it's in place, the Micromite BackPack PCB is then plugged into CON3 on the LCD board and secured in place using M3 x 6mm machine screws.

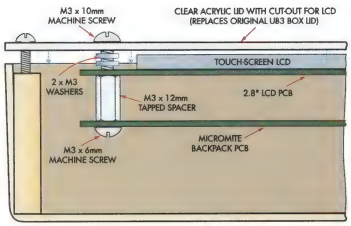


Fig.4: here's how to attach the LCD & Micromite BackPack PCB to the clear acrylic lid. The LCD goes through a cut-out in the lid and sits flush with its top surface.

This view shows the LCD/BackPack PCB assembly just before it is lowered into the case.

The next step is to drill holes in the lefthand side of the case to accept a panel-mount DC power socket and a 4-pin microphone socket (used for the sensor connection). These holes can be centred vertically on the panel, with each hole about 20mm in from its adjacent outside edge.

Drill small pilot holes to start with, then carefully enlarge each hole to size using a tapered reamer, so that the part just fits.

That done, the DC socket can be wired to a 4-pin female header as shown in Fig.5, with the red wire going to the centre pin terminal. The DC socket is then be secured to the case, after which the microphone socket can be fitted and wired to an 8-pin female header – see Fig.6.

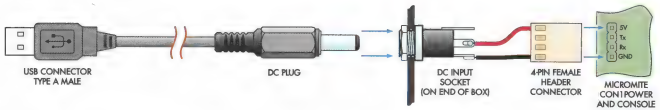


Fig.5: the Garage Parking Assistant is powered from a standard USB plugpack charger. To make a suitable power cable, cut off one end of a USB cable (retaining the type A male connector on the other end) and solder the red wire to the centre terminal pin of a DC plug and the black wire to the outside pin. The matching DC socket is mounted on the side of the UB3 box and is connected to a 4-pin female header which then plugs into CON1 on the Micromite PCB.

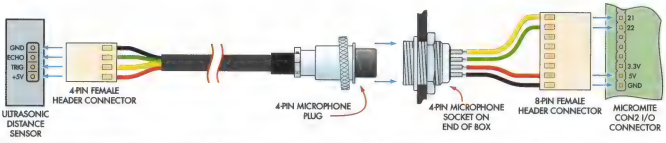


Fig.6: a cable with a 4-pin female header at one end and a 4-pin microphone plug at the other end connects the ultrasonic sensor to the display unit via a matching 4-pin socket. The microphone socket in turn is wired to an 8-pin female header which then connects to CON2 on the Micromite PCB. Note that the female headers shown in Figs.5 & 6 are not polarised, so make sure that they are orientated correctly when plugging them in.

The main unit can now be completed by plugging the headers into CON1 & CON2 on the BackPack PCB, then lowering the PCB assembly into the case and securing it at the corners using the supplied self-tapping screws.

Be careful when plugging in the two headers, as the connectors are not polarised. Basically, it's just a matter of making sure that ground (GND) from the DC socket (black wire) goes to GND on CON1 and that GND on the microphone socket goes to GND on CON2.

Note also that CON2 on the BackPack PCB has 18 pins; the 8-pin female header must be plugged in at the end that has the GND pin.

Fitting the sensor PCB

The ultrasonic sensor unit comes pre-assembled. It's just a matter of pushing the two sensors through their front panel holes as far as they will go to secure the unit in position. The sensors are a firm fit in the holes and that will usually be enough to hold the assembly in place.

Alternatively, a couple of small dabs of neutral-cure silicone can be used on the inside to ensure that the sensor unit can't be pushed back into the case.

The next step is to drill a 9.5mm hole through one side of the case (or through the top) and fit a rubber grommet. A 4-way cable (used to connect the sensor to the Micromite BackPack PCB) is then pushed through this grommet and wired to a 4-way female header as shown in Fig.6.

Either 6mm-diameter 4-core audio cable (with the shield braid cut short) or 4-wire telephone cable can be used here. The audio cable is a tight fit into the grommet, so it won't be necessary to secure it with a cable clamp. Conversely, some sort of clamping arrangement will probably be required if telephone cable is used.

The other end of this 4-way cable is connected to a 4-pin microphone plug. Make sure that the wires go to the correct pins on this plug, so that they mate with the correct wires on the socket when the two are connected together. If you are using audio cable, the shield braid can either be cut short or connected to the plug's metal shell.

The sensor unit is connected to the Micromite LCD Backpack via a 4-core cable. Power is derived from CON2 on the BackPack PCB.

Firmware Updates

For firmware updates for the Micromite and the Garage Parking Assistant, please check the author's website at geoffg.net/micromite.html

Note that the ultrasonic sensor assembly derives its power (5V) via this cable from CON2 on the Micromite BackPack PCB.

Power supply

5V USB plugpack chargers are cheap and the Garage Parking Assistant works perfectly with one of these. Be sure to select one with a generous current rating (500mA or more), as the unit can draw up to 250mA.

Fig.5 shows the details for the USB supply cable for one of these supplies. It's just a matter of cutting off one end of a USB cable (retaining the male type A connector at the other end) and soldering the red and black wires to the DC plug (red wire to the centre-pin terminal).

The other two wires in the USB cable (generally green and white) can be cut short, as they are not needed.

Another option is to use a 5V DC plugpack with a captive lead fitted with a DC plug. If the plug is the incorrect size, cut it off and fit one that does match the socket.

Loading BASIC

If you are going to load the BASIC program yourself or edit it later, you also need to make up a cable with a USB-to-serial converter as described last month. Then, after you have the program running, you can remove the converter and use the power cable instead.

This is because the program is designed to start running automatically whenever power is applied and after the program has been run once, you don't need to use the console again.

Mounting it in place

Having made the connections, the next step is to mount the two units in place. The LCD unit should be mounted on the garage wall at eye height, while the sensor should be mounted at bumper bar height.

Don't forget that you can easily adjust the green, yellow and red threshold values if necessary. Depending on how close you want to park to the wall, the default values should be fine in most cases. However, some people might want to increase the red threshold to (say) 15cm or even 20cm.

As stated earlier, all you have to do is touch the screen to bring up the main options menu and then touch the CHANGE button for the colour thresholds to bring up the relevant options menu. You then hit the CHANGE button for the threshold you want to change, enter in the new number on the virtual keypad, touch ENT and then FINISHED, and that's it! SC

Parts List

Micromite LCD BackPack Unit

1 PCB, code 07102122, 86 x 50mm (for 2.8-inch LCD)
1 ILI9341-based LCD, 320 x 240 pixels, 2.8-inch diagonal
1 UB3 ABS box, 130 x 67 x 43mm (Altronics H0153 or H0203, Jaycar HB6013 or HB6023)
1 pre-drilled clear acrylic lid to suit UB3 box
1 4-pin tactile switch, through-hole hole
1 100Ω vertical-mount side adjust trimpot (Altronics R2579, element14 9608044 or similar)
1 28-pin DIL low-profile IC socket
1 4-pin 0.1-inch male header (CON1)
1 18-pin 0.1-inch male header (CON2)
1 14-pin 0.1-inch female header socket (CON3)
1 6-pin 0.1-inch right-angle male header (CON4)
1 4-pin 0.1-inch female header
1 8-pin 0.1-inch female header
1 2.1mm or 2.5mm panel-mount DC socket (Altronics P0622 or P0623)
1 4-pin panel-mount microphone male socket (Altronics P0955 or Jaycar PP2010)
4 M3 x 12mm tapped spacers
4 M3 x 10mm machine screws
4 M3 x 6mm machine screws
8 M3 flat washers

Semiconductors

1 PIC32MX170F256B-50I/SP microcontroller programmed with ParkingAssistFull.hex (IC1) – see text. Note: a PIC32-MX170F256B-I/SP can also be used but will be limited to 40MHz)
1 Microchip MCP1700-3302E/TO voltage regulator (REG1)

Capacitors

1 47µF 16V tantalum or SMD ceramic (3216/1206)
2 10µF 16V tantalum or SMD ceramic (3216/1206)
2 100nF monolithic ceramic

Resistors (0.25W 5%)

1 10kΩ

Sensor Unit

1 ultrasonic distance sensor, HC-SR04, SRF05, SRF06, Parallax PING or DYP-ME007
1 UB5 ABS box, 82 x 54 x 30mm (Altronics H0155 or H0205 , Jaycar HB6005)
1 pre-drilled clear acrylic lid to suit UB5 box
1 9.5mm rubber grommet to suit 6mm-dia. cable (Jaycar HP0702)

Cable Parts

1 USB cable with a male type A connector (length to suit)
1 2.1mm or 2.5mm DC plug to suit DC socket (Altronics P0634A or P0635A, Jaycar PP0510 or PP0511)
1 4-pin female line microphone connector (Altronics P0950 or Jaycar PS2012)
1 4-pin 0.1-inch female header
1 length 4-core audio cable
1 200mm length of rainbow cable

Where To Buy Parts

A complete kit for the Micromite LCD BackPack is available from the Silicon Chip Online Shop. The clear lid with cut-out, to suit a UB3 Jiffy box, is available separately. We are also offering the ultrasonic distance sensor with a custom-cut UB5 jiffy box lid. See the Online Shop ad on page 88 for more details.

The Micromite BackPack PCB and programmed microcontroller can also be purchased separately.

Note that the kit does not include the boxes, mounting hardware, plugpack power supply, rubber grommet off-board headers and connectors or cable parts.

1-Wire Digital Temperature Sensor For The Raspberry Pi

By Greg Swain & Nicholas Vinen

If you just want to measure temperature, then using a Sense HAT with the Raspberry Pi (RPi) is overkill. A much cheaper, easier and more accurate option is to use a Dallas DS18B20 1-Wire Digital Thermometer Sensor.

THE DALLAS DS18B20 temperature sensor looks just like a TO-92 transistor but is actually much more complicated. Its internal chip not only includes a temperature sensor but also has a 12-bit on-board digital-to-analog converter, a 1-wire serial interface and all the necessary control logic. It's accurate to within ±0.5°C over the range of -10°C to +85°C and has a full operating temperature range from -55°C to +125°C.

In addition, each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. If you want to use multiple sensors, it's just a matter of connecting them in parallel.

A waterproofed and pre-wired version of the sensor is available and this can be purchased from the Silicon Chip Online Shop for just $5 plus postage. The sensor itself is housed in a small metal tube and is hooked up to a 1-metre long cable.

Apart from cost, the big advantage of the DS18B20 is that it's far more accurate than the Sense HAT: It's not only inherently accurate but can be well-separated from the RPi so that it is unaffected by heat generated by the RPi's ARM CPU. As a result, it doesn't require time for the readings to stabilise after switch on and we don't need to compensate for heat-soak from the RPi.

Connecting it to the RPi

Interfacing the DS18B20 sensor to the RPi's GPIO port couldn't be easier. As shown in Fig.1, there are just three wires to connect: the red wire goes to the +3.3V pin, the black wire goes to GND and the yellow data wire goes to GPIO4. In addition, a 4.7kΩ pull-up resistor must be connected between the data line and the +3.3V supply.

The easiest way to connect the wires is to terminate them in 1-way header sockets which are then plugged into RPi's GPIO port. Alternatively, you can cut two sections from a pin header socket (eg, Altronics P5380), plug them into the GPIO port and solder the sensor's leads to the pins. A small clamp attached to the case lid can be used to secure the cable in place.

The 4.7kΩ resistor can be connected by soldering its leads directly to the GPIO pads underneath the PCB.

Getting it going

You will need to install Raspbian on the RPi and set it up as described in the January and February 2016 is-

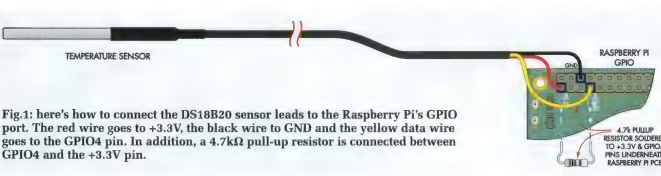


Fig.1: here's how to connect the DS18B20 sensor leads to the Raspberry Pi's GPIO port. The red wire goes to +3.3V, the black wire to GND and the yellow data wire goes to the GPIO4 pin. In addition, a 4.7kΩ pull-up resistor is connected between GPIO4 and the +3.3V pin.

The Raspberry Pi connects to your router via WiFi and streams the temperature readings to a web server so they can be accessed over the internet.

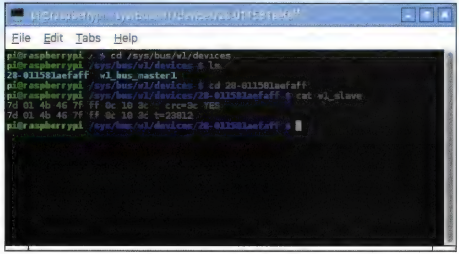


Fig.2: once the DS18B20 has been connected to the RPi, a number of commands are run in a terminal window to determine its ID address (see text).

sues of SILICON CHIP. If you don't have a Sense HAT module, you can leave out Steps 8-10 of the January article as they are not relevant.

Once you've done that and connected the DS18B20 temperature sensor, power up the RPi. You now need to tell it how to detect the sensor. To do that, enter the following command in a terminal window:

```
sudo nano /boot/config.txt
```

then move the cursor to the bottom of the file and add the following line:

```
dtoverlay=w1-gpio
```

Hit Ctrl-o and Ctrl-x to save the file and exit Nano, then reboot (**sudo reboot**) the RPi so that the changes take effect.

(Note: on older versions of Raspbian, it may be necessary to add the lines **w1-gpio** and **W1_therm** to the end of **/etc/modules**).

Once the RPi is up and running again, enter the following commands into a terminal window:

```
cd /sys/bus/w1/devices
ls
```

Your DS18B20 temperature sensor's unique ID address will now be listed in the terminal window followed by **w1_bus_master1** – see Fig.2. If you multiple sensor's connected in parallel, then multiple IDs will be listed (one for each sensor).

In our case, the sensor's ID is **28-011581aefaff** and we can now open the sensor's file to view the temperature reading as follows:

```
cd 28-011581aefaff
cat w1_slave
```

This will return two lines of data, as shown in Fig.2. The first line is a cyclic redundancy check (CRC) and if it ends in "YES", then the reading was successful. The second line displays the temperature reading, in this case **t=23812**. This is the temperature in °C x 1000, so we simply divide by 1000 to get the temperature: ie, 23812 ÷ 1000 = 23.812°C.

The 4.7kΩ pull-up resistor can be directly soldered to the GPIO pins.

Python program

We don't want to have to go through this rigmarole every time we want to

Fig.3: readtemp.py

```
import time
import os
import re

sensor_names = {"011581aefaff": "indoor"} #Substitute your sensor's ID

def list_onewire_sensors():
    path = '/sys/bus/w1/devices'
    return [f for f in os.listdir(path) if not os.path.isfile(os.path.join(path, f)) and f.s

def read_onewire_sensor(name):
    path = '/sys/bus/w1/devices'
    file = open(os.path.join(path,name,'w1_slave'), 'r')
    line1 = file.readline()
    line2 = file.readline()
    file.close()
    if line1.endswith(' YES\n'):
        info = re.search('(\\d+)\n?$', line2)
        if info and int(info.group(1)) > 0:
            return int(info.group(1)) / 1000.0
    return '?';

def getmsg(entities):
    tm = time.strftime("%d/%m/%Y %H:%M:%S", time.localtime())
    msg = "[%s]" % tm

    deg = "&deg;" if entities else u"\u00B0"

    onewire_sensors = list_onewire_sensors()
    for sensor in onewire_sensors:
        temp = read_onewire_sensor(sensor);
        msg += ' '+( sensor_names[sensor[3:]] if sensor[3:] in sensor_names else sensor[3:]

    return msg

while True:
    print(getmsg(False))
    time.sleep(5)
```

read the temperature, so the answer is to automate the procedure using a simple Python program. Better still, we can then stream the readings to Apache Web Server on the RPi, so that we can access the readings over the internet (or on the local network) using a web browser.

Let's get the Python program running first. Fig.3 shows the code – just download the **readtemp.py** file from the SILICON CHIP website to the RPi's **/home/pi** folder, then launch Python 3 from a terminal window using the following commands:

xhost + (if you're running it headless)
sudo idle3 &

Wait until Python 3 launches, then open **/home/pi/readtemp.py** and click **Run Module**. You should see the temperature readings appear as shown in Fig.4, with the reading updated every 5s.

OK, let's take a closer look at the program. The new code has two functions to assist with reading the DS18B20 1-Wire sensor temperature, plus some extra code to display the results.

The **list_onewire_sensors** function scans the **/sys/bus/w1/devices** directory for subdirectories starting with "28-" and adds the sensor's name, which includes its unique serial number, to an array. The returned array thus contains one entry for each DS18B20 sensor that has been detected.

The **read_onewire_sensor** function receives the name of one of the sensors (from the list) and interrogates that sensor. It reads two lines, both of which contain the full sensor response. As stated, the first one has a flag indicating whether the CRC is valid, while the second line contains the decoded temperature value.

This function reads both lines and, if the CRC is valid, returns the temperature reading in °C as a floating point value. If an error occurs, it returns a string containing a question mark.

We also have a list called **sensor_names** which can be used to map the cryptic unique ID for a given sensor to a more useful name such as "indoor", "outdoor", etc. That way, you can name the sensors and the temperature for each sensor is then displayed after its name.

The test script also initialises a string with the current date and time. It then calls the first helper function to get a list of sensors and then, for each sensor, gets the name and temperature and adds it on to the end of that string. Finally, that string is printed, as shown in Fig.4.

If you want to change the update time, just edit the last line of the script.

Web access

We've also adapted the **index.py** script originally used last month so

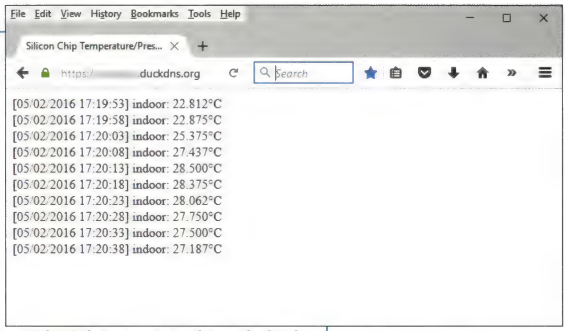


Fig.5 (above): the temperature readings as displayed in a web browser. The rapid increase in temperature was the result of briefly holding the temperature sensor between two fingers.

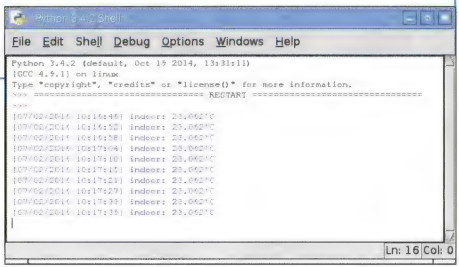


Fig.4: this is the output that appears when running readtemp.py in Python on the RPi. The reading updates about every five seconds but this is easy to change.

that the Apache 2 Web Server could serve readings from the Sense HAT. We've left the code to display the readings from the Sense HAT in place but wrapped it with an "exception handler" so that if the Sense HAT isn't installed, its absence is ignored.

We then use the same code from the **readtemp.py** script to append the DS18B20 reading(s) to the end of each line that's displayed. If you can physically connect both the Sense HAT and some DS18B20 temperature sensors, all the readings at any particular instant will be shown on the same line.

If you only have a DS18B20 sensor connected, its readings will be displayed as shown in Fig.5. And if you have several DS18B20s connected in parallel, all their readings will be displayed. You can edit the **sensor_names =** line to distinguish between them – just add a comma after each preceding entry and add each additional sensor's ID address and name (with everything enclosed by one set of parentheses).

Apart from adding code to support the DS18B20 sensors, we've also improved the program to give more consistent time intervals between readings. Basically, the page load time has now been taken out of the equation.

Setting up the web server

Installing and getting the Apache Web Server going is straightforward – just follow the step-by-step procedure described in the February 2016 article. As before, the **index.py** script (embedded in **index.py.zip**) can be downloaded from the SILICON CHIP website, unzipped and copied to **/var/www/html**.

Don't forget to set up password access and a dynamic DNS service (eg, Duck DNS) if you want to access the temperature readings over the internet. It's also a good idea to install Fail2Ban, to temporarily ban anyone who makes too many failed log-in attempts.

Once the set-up is complete, you can browse to the RPi's web server by entering your local IP, WAN IP or dynamic DNS address into your browser to display the temperature readings. By default, the reading updates every five seconds but you can easily change this by altering the two **interval=5** values in **index.py**; eg, **interval=30** updates the reading every 30 seconds.

Alternatively, you can add a switch to the website address, as described on page 58 of the February issue. SC

Delta Throttle Timer

By JOHN CLARKE

This handy device will activate a timer and relay when you're accelerating or decelerating hard. It does this by responding to how quickly you're moving the accelerator pedal. In fact, it is a general purpose version of the QuickBrake project presented in the January 2016 issue.

If you read the article on the QuickBrake project, you will know that it turns on your brake lights before the brakes are actually applied, by sensing that you have lifted off the throttle very rapidly, just as you do before a heavy application of the brakes.

This gives following drivers an early warning (via an earlier brake light turn-on) that you are about to decelerate heavily.

But this version of the circuit, the Delta Throttle Timer, can respond to heavy applications of the throttle too.

Say you're driving along and the road passes through a section of winding country road. As you approach those bends, you decide to push it along a lot harder – and your foot goes down fast.

You wind out the engine in second gear, flick the lever across to third and then flatten the throttle again. A corner approaches and you lift off, turn in and then right at the apex, get back hard on the power.

The Delta Throttle Timer (DTT) has all the time been watching the voltage coming from the throttle position sensor.

When it recognises how fast you're pushing down on the throttle, it activates a timer which in turn controls a relay. If that relay is connected to (say) an intercooler water spray, you'll be cooling the core even before the car comes up on boost!

Set the timer for an interval of 30 seconds and that's how long the spray will stay on for but you can repeatedly extend the time if you push down fast on the throttle again before the relay times out.

And when you go back to gentle driving, the spray will then turn off.

But there are other possible uses. The DTT is the ideal way of triggering engine and transmission modifications.

For example, you could set it up so that when you drive with fast throttle movements the turbo boost increases.

Or you can use the DTT to automatically switch the transmission's Power/Economy button to Power mode when you're really pushing it along. And again, when you revert to a more gentle mode, the DTT will switch the auto transmission back to Economy Mode.

Still with a turbo car, because the DTT can be configured to also measure quick throttle lifts (as in the QuickBrake), you can also use the device to control an electric blow-off valve.

In that application, the timer would be set for a very short period – say one second – so that whenever you quickly lift the throttle (eg, for a gear-change), the blow-

Main Features

- Has a 0-5V signal input range
- Powers a relay when a specific rate of voltage change occurs
- Adjustable rate threshold
- Adjustable timer from 0.1s to more than 100 seconds
- Selectable rising or falling voltage rate switching
- Power-up delay to prevent false triggering at ignition-on

off valve will open. However, at idle, the valve will stay shut, avoiding those problems where intake air can be drawn in through the open valve.

The DTT is easy to build and easy to connect and set up. Apart from the device that you are controlling, only three connections are needed to the car's wiring: ignition-switched +12V, chassis (earth or GND) and the throttle position sensor. Alternatively, if your car does not have a throttle position sensor or if the TPS is difficult to access, you could use the MAP (manifold absolute pressure) sensor instead, then

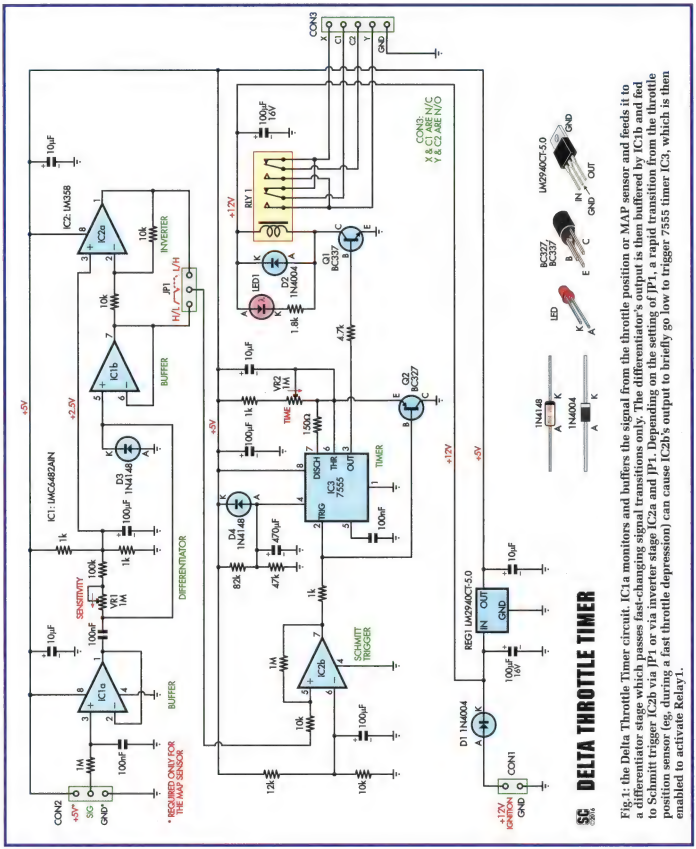


Fig.1: the Delta Throttle Timer circuit. IC1a monitors and buffers the signal from the throttle position or MAP sensor and feeds it to a differentiator stage which passes fast-changing signal transitions only. The differentiator's output is then buffered by IC1b and fed to Schmitt trigger IC2b via JP1 or via inverter stage IC2a and JP1. Depending on the setting of JP1, a rapid transition from the throttle position sensor (eg, during a fast throttle depression) can cause IC2b's output to briefly go low to trigger 7555 timer IC3, which is then enabled to activate Relay1.

Suggested uses

When configured to measure quick downwards throttle movements:

- Switching engine management and auto transmission control modifications in and out
- Automatic switching of the Power/Economy auto transmission button
- Automatic turbo boost increase with hard driving
- Intercooler water spray and/or intercooler fan control

When configured to measure quick throttle lifts:

- Electronic blow-off valve control
- Early brake light illumination (as in the QuickBrake)

you need four connections: switched +12V (from ignition), +5V, signal and chassis.

Circuit description

Fig.1 shows the circuit and is almost identical to that of the QuickBrake. It uses two dual op amps (IC1 & IC2) and a 7555 timer (IC3). The circuit is designed to detect the rapid change of voltage from the TPS or MAP sensor and then switch on a relay. The relay then stays on for a preset period of time before it is switched off.

The dual op amps are an LMC6482-AIN (IC1) and an LM358 (IC2) and these run from a +5V supply.

The signal voltage from the MAP sensor or TPS is fed via a 1MΩ resistor with a 100nF low-pass filter capacitor to the non-inverting input of IC1a. This operates as a unity gain buffer. Its pin 1 output drives a differentiator comprising a 100nF capacitor, 1MΩ trimpot VR1 and a series-connected 100kΩ resistor.

The differentiator acts as a high-pass filter, letting fast-changing signals through but blocking slowly-changing signals. This is exactly what we want in order to sense the sudden change as the driver lifts off or shoves the accelerator down.

The differentiator is connected to a +2.5V reference which is derived from the +5V rail with a voltage divider using 1kΩ divider resistors, bypassed with a 100µF capacitor. With no signal passing through the 100nF differentiator capacitor, the output voltage on the VR1 side of the capacitor sits at +2.5V.

Depending on how the vehicle is being driven, the MAP or TPS signal will either be steady or decreasing or increasing in voltage.

Exactly how much signal passes through the 100nF differentiator capacitor is dependent on the rate of voltage change and the setting of trimpot VR1. VR1 sets the time-constant of the differentiator so high resistance settings for VR1 will mean that the circuit responds to more slowly changing signals from the TPS or MAP sensor.

The differentiator output is buffered using op amp IC1b and it provides the high-to-low (H/L) output. IC2a is wired as an inverting amplifier and it inverts the output from IC1b. This provides the low-to-high (L/H) output.

Jumper link JP1 then selects the output of IC1b or IC2a. This allows triggering on a falling (H/L) or rising (L/H) input signal. The selected signal is applied to IC2b, a Schmitt trigger stage. IC2b has its inverting input connected to a 2.27V reference derived using 12kΩ and 10kΩ resistors connected across the 5V supply. The non-inverting input is connected to JP1 via a 10kΩ resistor. A 1MΩ hysteresis resistor connects between the non-inverting input and IC2b's output.

With no signal passing through the differentiator, the voltage applied to the non-inverting input via the 10kΩ resistor to IC2b is 2.5V. Since the inverting input is at 2.27V, the output of IC2b will be high, at around +4V. This output goes low when the signal from JP1 drops below the 2.27V threshold. The associated 1MΩ feedback resistor provides a degree of hysteresis so that IC2b's output does not oscillate at the threshold voltage.

Relay timer

IC2b's output drives the pin 2 trigger input of IC3, a 7555 timer, via a 1kΩ resistor. IC3 is triggered when pin 2 drops below 1/3rd the 5V supply, at +1.67V.

When triggered, IC3's output at pin 3 goes high, turning on transistor Q1 and relay RL1. Diode D2 is connected across the relay coil to quench the spike voltages that are generated each time transistor Q1 turns off. Q1 also drives LED1 via a 1.8kΩ resistor to indicate whenever the relay is energised.

Before IC3 is triggered, its pin 3 output and its discharge pin (pin 7) are both low. So pin 7 causes the negative side of the 100µF capacitor to be pulled toward 0V via a 150Ω resistor.

Whenever IC2b's output goes low it also turns on transistor Q2, wired as an emitter follower. The transistor keeps the negative side of a 100µF capacitor tied at 0V. This keeps the 100µF capacitor charged while ever IC2b's output is low.

When IC2b's output goes high, Q2 is off and the 100µF capacitor discharges via trimpot VR2 and the series 1kΩ resistor, so that the negative side of the capacitor rises toward the 5V supply.

When the negative side of the 1µF capacitor rises to 2/3rds of the 5V supply (about +3.3V), the threshold voltage for pin 6 is reached.

At this point, pin 3 goes low and transistor Q1 and the relay are switched off. IC3's timing period can be set from around 100ms up to more than 100 seconds, using VR2.

Power-up delay

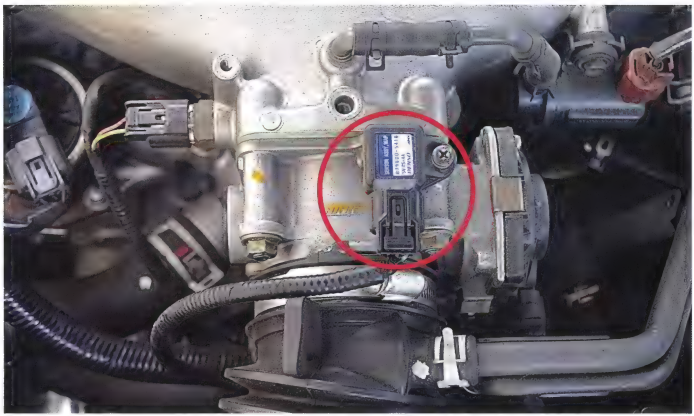
The components connected to pin 4 of IC3 are used to provide a power-up delay. When the vehicle ignition is switched on, the DTT circuit is prevented from operating the relay for a short period. The delay components comprise a 470µF capacitor, diode D4, and 47kΩ and 82kΩ resistors. When power is first applied to the circuit, the 470µF capacitor is discharged and so pin 4 is held low. This holds IC3 in reset so its pin 3 cannot go high to drive Q2 and the relay.

IC3 becomes operational after about a second when the 470µF capacitor charges via the 82kΩ resistor to above operating threshold for pin 4. The 47kΩ resistor is included to set the maximum charge voltage at 1.8V. That's done so the 470µF capacitor will discharge quickly via diode D4 and the 47kΩ resistor when power is switched off.

Power for the circuit comes via the +12V ignition supply. Diode D1 provides reverse polarity protection and an LM2940CT-5.0 automotive regulator (REG1) provides the 5V supply for all the circuitry, with the exception of the relay and LED1.

Construction

The DTT is built on a PCB coded



This design can use either a throttle position sensor or a MAP sensor (shown ringed above) – the choice is often made by the easiest access. On this Honda VTEC engine, the MAP sensor is obviously more accessible so it would be the better choice.

05102161 and measuring 105.5 x 60mm. It can be fitted into a UB3 plastic utility box that measures 130 x 68 x 44mm, with the PCB supported by the integral side clips of the box. Alternatively, you can mount the PCB into a different housing on short stand-offs using the four corner mounting holes.

Fig.2 shows the component layout for the PCB. The low-wattage resistors can be installed first. The respective resistor colour codes are shown in Table 1 but you should also use a digital multimeter to check each resistor before it is installed. The diodes can go in next and these need to be inserted with the correct polarity with the striped end (cathode, K) orientated as shown.

Take care when installing the IC sockets (optional) and the ICs. Make sure that their orientation is correct and that the correct IC is inserted in each place.

REG1 is installed with its leads bent over at 90° so as to fit into the allocated holes in the PCB. The regulator is then secured to the PCB using an M3 x 6mm screw and M3 nut before its leads are soldered. The 3-way pin header for JP1 is installed now with the shorter pin length side inserted into the PCB, leaving the longer pin length for the jumper link.

The two long wire links can be installed now and then the capacitors can go in. The electrolytic types must be installed with the polarity shown, with the plus side oriented toward the sign as marked on the PCB. The ceramic and polyester capacitors (MKT) can be installed with either orientation on the PCB.

Install transistors Q1 and Q2 next. Make sure that Q1 is a BC337 and Q2, BC327. LED1 must be installed with its anode side (longer lead length) orientated as shown. The LED is normally just used to provide a relay-on indication that is useful when testing, so the LED can be mounted close to the PCB.

VR1 and VR2 can go in next. Both are 1MΩ multi-turn top-adjust types and the screw adjustment needs to be orientated as shown. This is so that faster pedal movement for triggering set by VR1 and longer time periods set by VR2 are achieved with clockwise rotation.

The screw terminal blocks are installed with the open wire entry sides facing outwards. The 5-way screw terminal block (CON3) consists of one 2-way and one 3-way block which

It's been done before

While the Delta Throttle Timer may be a new concept to many readers, a similar approach is used in nearly all recent model cars. The speed with which the throttle is moved helps determine the rate of transient ignition timing change and the injection of fuel (the latter is the accelerator pump, if you like).

In cars with sophisticated electronic transmission control, gear down-changes are also determined by how fast the throttle is moved as much as it is by how far the throttle is moved.

In fact, in some cars the driver learns to use this facility by:

- Moving the throttle slowly when a down-change isn't needed.
- Quickly moving the throttle a short distance when a one-gear down-change is wanted.
- Quickly moving the throttle a longer distance when two-gear down-changes are wanted.

With the DTT able to control anything that can be electrically turned on and off, the driver will be able to activate (either consciously or unconsciously) a whole range of devices

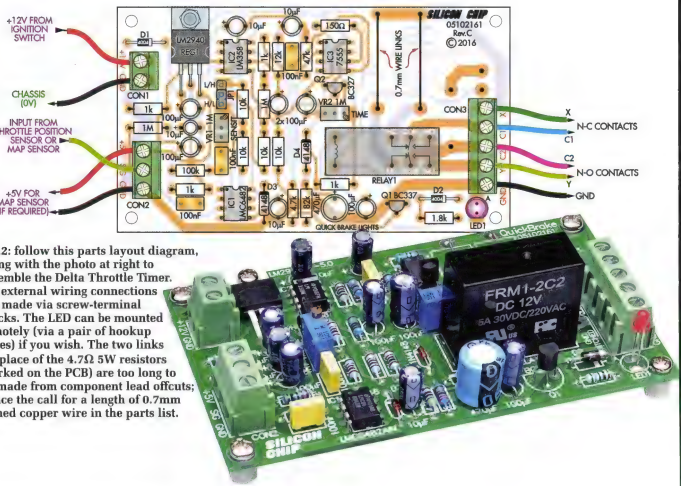


Fig.2: follow this parts layout diagram, along with the photo at right to assemble the Delta Throttle Timer. All external wiring connections are made via screw-terminal blocks. The LED can be mounted remotely (via a pair of hookup wires) if you wish. The two links (in place of the 4.7Ω 5W resistors marked on the PCB) are too long to be made from component lead offcuts; hence the call for a length of 0.7mm tinned copper wire in the parts list.

are simply dovetailed together before installing them on the PCB.

Finally, complete the PCB assembly by fitting the relay.

Initial testing

Apply power to the +12V and GND terminals of CON1 and check for 5V at CON1 between the +5V & GND terminals. If the voltage is within the range of 4.85-5.15V, then this is OK. If the voltage reads 0V, the 12V supply may have been connected with reversed polarity or D1 may have been orientated the wrong way.

Before doing any adjustments, trimpots VR1 and VR2 should be wound anticlockwise until a faint click is heard, indicating that the adjustment is set fully anticlockwise. This sets VR1 for maximum sensitivity to sensor voltage change and VR2 for minimum relay on-time. Then place a jumper link on JP1 in the H/L position.

To simulate a throttle position sensor, connect a linear 10kΩ potentiometer to CON2, with the outside terminals connected to GND and +5V and the wiper to the SIG (signal) input. Adjust the 10kΩ potentiometer clockwise and then wind it quickly anticlockwise. The relay should switch on and LED1 should light. You can now check the

Uh Oh, it won't suit all cars!

As constructed, the DTT will work with a throttle-position sensor that has an output that varies within the 0-5V range. Just about all cars use sensors that increase in voltage with throttle opening.

However, the DTT can also be used in cars where the sensor voltage decreases with an increasing throttle opening (just move link LK1 to the H/L position to trigger with decreasing sensor voltage).

What if you want to use an input signal that rises as high as 12V? In this case, you can attenuate the incoming signal to a range that can be accepted by IC1a. To do this, connect a 470kΩ resistor in parallel with the 100nF capacitor that connects between pin 3 of IC1a and ground (ie, immediately to the left of IC1 on the PCB).

Also, some older cars use a throttle position switch, rather than a variable sensor and in this case you cannot use the DTT.

So before buying the kit, the first step is to determine whether you have a TPS or MAP sensor in your car.

If you don't know whether you have a switch or variable sensor, measure the output of the throttle position sensor.

With one multimeter probe earthed, a TPS will have a voltage signal that varies somewhere within the 0-5V range as you manually adjust the throttle.

Throttle position sensors come in a wide variety of shapes and styles – here's just a small selection we found being offered for sale. Unless yours is faulty (very rare) you should be able to tap across the one already fitted to your vehicle. If you don't know where to find the TPP, perhaps this is not the right project for you!

effect of adjusting VR1 clockwise; this will mean that the 10kΩ potentiometer will need to be rotated more quickly clockwise before the relay switches on. VR2 can then be rotated clockwise to set more on-time for the relay.

Installation

Most modern vehicles will have a TPS (and possibly a MAP sensor as well) and so this sensor can be used as the signal source for the DTT. In this case, only the signal input terminal is used and isconnected to the signal wire from the TPS which will normally be connected to the accelerator pedal. In some cases though, it may be located on the inlet manifold butterfly valve. The connections can be found by checking the wiring against a schematic diagram and connecting to the wiper of the TPS potentiometer. Alternatively, you could probe the TPS wires to find the one that varies with throttle position. Note that some TPS units will have two potentiometers plus a motor.

Use the potentiometer wiper output that varies with throttle pedal position. Once you have identified the correct wire from the TPS, you can connect a wire from it to the DTT PCB using a Quick Splice connector (Jaycar Cat HP-1206; packet of four). Just wrap it around the existing TPS wire and the new wire and simply squeeze it to make a safe connection.

If you have an older vehicle, then it will not have a TPS or engine management. In this case, a MAP sensor can be used to monitor the inlet pressure.

Using a MAP sensor for manifold pressure readings is suitable only for petrol engines though, not diesels. The 5V supply provided on the DTT PCB at CON2 can be used to supply the MAP sensor. It is not critical which MAP sensor is used. A secondhand MAP sensor can be obtained from a wreckers' yard. Holden Commodore MAP sensors are common. Alternatively, you can obtain a new one from suppliers such as: www.cyberspaceautoparts.com.au/contents/en-uk/d3721_Holden_Map_Sensors.html

The voltage output of a MAP sensor usually decreases with increasing vacuum; typically 0.5V with a complete vacuum and up to about 4.5V at atmospheric pressure. This is similar to a TPS sensor which has an output of about 0V at no throttle and 5V at maximum throttle. Note that the TPS output will only vary with throttle position when the ignition is on. And naturally a MAP sensor will only vary its output with changes in manifold pressure, ie, when the engine is running.

You can now install it in your car. Having made the connection to the TPS or MAP sensor, the next step is to measure the output of the sensor and confirm that it varies over a 0-5V range when the throttle is moved. If so, install link LK1 in the "L/H" position so that the circuit triggers with increasing sensor voltage (ie, for quick throttle presses).

You can now connect ignition-switched +12V, earth and the throttle position signal to the DTT. Note that to get the throttle signal, you simply tap into the throttle position output wire – you don't need to cut it. This latter connection can be made either at the ECU or at the throttle body itself.

Next, adjust both trimpots fully anti-clockwise – this increases the sensitivity of the DTT to throttle changes

Similarly, there's a huge range of MAP sensors available (that stands for Manifold Absolute Pressure, by the way). Perhaps the easiest way to identify the MAP sensor (apart from any label which says so!) is the fact that MAP sensors will normally have three wires: +V, 0V and signal.

Parts List

1 double-sided PCB, code 05102161, 105.5 x 60mm
1 UB3 plastic utility box, 130 x 68 x 44mm
1 12V DC DPDT PCB-mount relay (Jaycar SY-4052 [5A], Altronics S4190D [8A], S4270A [8A]) (RLY1)
1 set of Quick Splice connectors (Jaycar HP-1206 or similar)
2 2-way PCB-mount screw terminals, 5.08mm spacing (CON1,CON3)
2 3-way PCB-mount screw terminals, 5.08mm spacing (CON2,CON3)
1 3-way pin header, 2.54mm pin spacing (JP1)
1 2.54mm jumper shunt (JP1)
2 1MΩ vertical multi-turn trimpots (VR1,VR2)
4 tapped spacers, M3 x 6.3mm*
5 M3 x 6mm screws*
1 M3 nut
100mm length 0.7mm tinned copper wire (LK1 & LK2)

Semiconductors

1 LMC6482AIN dual CMOS op amp (IC1)
1 LM358 dual op amp (IC2)
1 7555 CMOS timer (IC3)
1 LM2940CT-5.0 3-terminal 5V low-dropout regulator (REG1)
1 3mm or 5mm red LED (LED1)
1 BC337 NPN transistor (Q1)
1 BC327 PNP transistor (Q2)
2 1N4004 1A diodes (D1,D2)
2 1N4148 diodes (D3,D4)

Capacitors

1 470µF 16V PC electrolytic
5 100µF 16V PC electrolytic
4 10µF 16V PC electrolytic
3 100nF MKT polyester

Resistors (0.25W, 1%)

2 1MΩ	1 100kΩ
1 82kΩ	1 47kΩ
1 12kΩ	4 10kΩ
1 4.7kΩ	1 1.8kΩ
4 1kΩ	1 150Ω

**4 tapped spacers and 4 M3 screws are not required if PCB is mounted in a UB3 box.*

and reduces the timer's "on" time to a minimum. (Note that both these pots are multi-turn so they don't have a distinct end "stop".)

If using a TPS, turn the ignition on but don't start the car. Wait five seconds (remember: the DTT has an ignition-on reset pause), then quickly push down on the throttle and check that the relay pulls in and that the LED lights. The relay should then click out (and the LED go off) fairly quickly, so adjust the righthand trimpot clockwise and again push down quickly on the accelerator pedal. This time, the "on" time should be longer.

If using a MAP sensor, the engine needs to be running.

The next step is to adjust the left-hand trimpot clockwise until the DTT responds only when the throttle is being pushed down with "real life" quick movements. That done, move LK1 to the H/L position and confirm that the DTT now responds only to quick throttle lifts.

Finally, move LK1 back to the L/H position if you want the circuit to trigger on a rising sensor voltage.

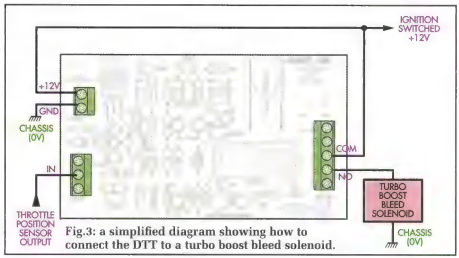


Fig.3: a simplified diagram showing how to connect the DTT to a turbo boost bleed solenoid.

Setting Up

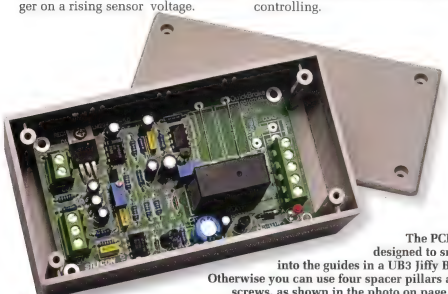
Setting up the DTT is also easy. Normally, you'll find that driving on the road actually involves different speeds of throttle movement than used during the static set-up, so the sensitivity control will need to be adjusted accordingly. The length of time that you set the timer to operate for will depend very much on what you are controlling.

The prototype was used to automatically activate the Power mode in an auto transmission, an easy task to accomplish.

All you have to do is wire the Normally Open (NO) and Common (C) terminals of the relay in parallel with the Power/Economy switch (this still allows the switch to be manually used as an over-ride). In this application, a DTT timer "on" period of about 7.5 seconds was ideal – any longer and sometimes the car would hang on too long in third gear before finally changing up to fourth, while lesser time periods meant that sometimes the DTT would click out of Power mode while the driver was still pushing hard.

Incidentally, the driveability of the car was transformed by the use of the DTT in this way – after all, it's a bit like having a little man sitting on the centre console, ready to push in the Power/Economy button every time you slam the throttle down fast!

The PCB fits straight into a 130 x 68 x 42mm zippy box, so when the system is working correctly, the board can be inserted into the box and tucked out of sight. SC



The PCB is designed to snap into the guides in a UB3 Jiffy Box. Otherwise you can use four spacer pillars and screws, as shown in the photo on page 42.

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	1MΩ	brown black green brown	brown black black yellow brown
❑	1	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	82kΩ	grey red orange brown	grey red black red brown
❑	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	1	12kΩ	brown red orange brown	brown red black red brown
❑	4	10kΩ	brown black orange brown	brown black black red brown
❑	1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	1	1.8kΩ	brown grey red brown	brown grey black brown brown
❑	4	1kΩ	brown black red brown	brown black black brown brown
❑	1	150Ω	brown green brown brown	brown green black black brown

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GREEN WH-3056

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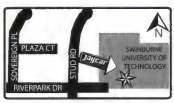

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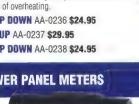

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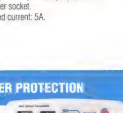

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- Max. switching current: 20A
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- 87(L) x 60(W) x 32(H)mm

DOUBLE POINTS FOR NERD PERKS CARD HOLDERS ON THESE POWER ACCESSORIES

$34.95 DOUBLE POINTS

12VDC 8A Dimmer / Motor Speed Controller MP-3209

The pulse width modulation (PWM) used in this controller allows you to vary the output from 0 to 100% while maintaining a very high efficiency. When used on motors this ensures full torque is available at very low speed and the motor won't shudder at start-up. Operates on any 12VDC system and capable of controlling devices rated at up to 8 amps.

- 95(L) x 47(W) x 26(H)mm

FROM 25¢/m DOUBLE POINTS

General Purpose Power Cables

FLEXIBLE LIGHT DUTY Suitable for general purpose wiring. 13x 0.12mm. PVC insulation. 0.6A rated current: WH-3016 **$0.25/M**
HEAVY DUTY Suitable for 250V wiring. 24 x 0.2mm. PVC insulation. 7.5A rated current. WH-3040 **$0.5/M**
EXTRA HEAVY DUTY Suitable for 250V wiring. 32 x 0.2 mm. PVC insulation. 10A rated current WH-3052 **$0.70/M**

$15.95 DOUBLE POINTS

Stainless Steel Wire Stripper, Cutter, Pliers

TH-1841

High quality precision stripper/cutter. Spring-loaded with locking jaws, rubber handles for added comfort. Cuts wire up to 3.0mm. Strips wire up to 2.6mm.

DOUBLE POINTS ON ALL POWER CABLES DOUBLE POINTS

FROM $1.25/m DOUBLE POINTS

AC Mains Cables

TWO CORE MAINS FLEX 7.5A WB-1560 **$1.25/M**
THREE CORE MAINS FLEX 10A WB-1562 **$2.50/M**

EARN A POINT FOR EVERY DOLLAR SPENT AT ANY JAYCAR COMPANY STORE* & BE REWARDED WITH A $25 JAYCOINS CASH CARD ONCE YOU REACH 500 POINTS! *Conditions apply. See website for T&Cs.

SIGN-UP IN-STORE OR ONLINE TODAY BY VISITING: www.jaycar.com.au/nerdperks

ALL ABOUT BATTERIES

LIFEP04 BATTERIES

FROM $9.95

SB-2317

3.2V LIFEP04 Rechargeable Batteries

Lithium iron phosphate (LiFePO4) is a more chemically stable type of lithium rechargeable cell that is becoming increasingly popular, due to increased safety and longer cycle life over traditional Li-ion cells.

14500 600MAH SB-2305 **$9.95**
18650 1600MAH SB-2307 **$17.95**
26650 3000MAH SB-2317 **$24.95**

LI-ION BATTERIES

FROM $9.95

SB-2300

Rechargeable Li-Ion Batteries

Choose between nipple or solder tabs to make into battery packs for replacement or new projects.

NIPPLE CONNECTION:
14500 800MAH 3.7V SB-2300 **$9.95**
18650 2600MAH 3.7V SB-2308 **$19.95**
26650 3400MAH 3.7V SB-2315 **$24.95**
SOLDER CONNECTION:
14500 800MAH 3.7V SB-2301 **$10.95**
18650 2600MAH 3.7V SB-2313 **$21.95**
26650 3400MAH 3.7V SB-2319 **$25.95**

NICKEL METAL HYDRIDE (NI-MH) RECHARGEABLE BATTERIES

1.2A Rechargeable Ni-MH Battery

Nickel Metal Hydride (Ni-MH) batteries offer superior features to Nickel-Cadmium batteries.

- No memory effect
- Higher current capacity than Ni-Cd batteries
- High drain performance

NIPPLE CONNECTION: SB-1706
AA 2000MAH SB-1706 **$4.25**
AA 2000MAH 4 PACK SB-1737 **$15.95**
AAA 900MAH 4 PACK SB-1739 **$10.95**
SOLDER TABS CONNECTION:
AA 2000MAH SB-1708 **$4.45**

FROM $4.25

1.2V NI-MH Rechargeable Batteries

D 9000MAH NIPPLE 2 PACK
SB-1734 **$44.95**
C 4500MAH NIPPLE 2 PACK
SB-1733 **$22.95**

FROM $22.95

SB-1734

Panasonic Eneloop Ni-MH 1.2V 2000mAH

This range of Panasonic eneloop batteries have numerous advantages over regular rechargeables. They include low self-discharge, they are pre-charged so can be used right out of the packet, and can be recharged up to 1800 times. After 5 years of storage they will retain 70% of their capacity once fully charged. A far more environmentally friendly option than churning through dozens of alkalines.

2000MAH AA 2 PACK SB-2930 **$16.95**
2000MAH AA 4 PACK SB-2931 **$29.95**
900MAH AAA 2 PACK SB-2932 **$16.95**
800MAH AAA 4 PACK SB-2933 **$32.95**

FROM $16.95

Panasonic XX High Capacity Eneloop Ni-MH 1.2V

For even more demanding applications the Panasonic XX High Capacity range are perfect. Can be recharged 500 times, and will retain 75% of their capacity after a year in storage. They can also be used in sub-zero temperatures (-20°C) without issue.

900MAH AAA 4 PACK SB-2938 **$39.95**
2500MAH AA 4 PACK SB-2936 **$33.95**

FROM $33.95

SB-2938

COMPUTER BACKUP

BATT LITHIUM 1/2AA 3.6V

High capacity batteries used in computers to retain date, time and configuration information. Also useful for long shelf life or fitting into difficult or sealed access areas. Up to 10 years storage life.

HALF AA 900MAH NIPPLE SB-1770 **$11.95**
HALF AA 900MAH AXIAL LEAD SB-1771 **$13.95**
AA 2000MAH NIPPLE SB-1774 **$16.95**
AA 2000MAH AXIAL LEAD SB-1775 **$18.95**

FROM $11.95

BATTERY CHARGERS

Batteries not included.

$24.95

Universal Ni-Cd/Ni-MH Battery Charger WITH CUT-OFF MB-3514

- Recharges: AAA, AA, C , D and 9V batteries
- Cut-off function
- Accepts various combinations of batteries
- 199(L) x 100(W) x 46(H)mm

$29.95

2 Hour Fast Charger for AA/AAA Ni-MH Batteries MB-3549

Utilises Delta V voltage detection. Charges batteries to optimal level. Charge state can be monitored on the integrated electric blue LCD. Includes car cigarette lighter and mains charger cords.

- 1150mA charging current for AA batteries
- 600mA charging current for AAA batteries
- 105(L) x 68(W) x 30(H)mm

$59.95

Smart Battery Charger

Ni-CD & Ni-MH MB-3551

Chargers up to 10 x AA or AAA cells and 2 x 9 volt batteries. Uses Delta V sensing to achieve the maximum charge. A maximum charging timer protects against overcharging & individual LEDs show battery status.

- Mains power & 12V car adaptor supplied
- 220(W) x 40(H) x 115(D)mm

$89.95

Universal Programmable Balanced Battery Charger MB-3632

Charges Li-Ion, Li-Po, Ni-Cd, Ni-MH and lead acid batteries. Li-Po batteries are balance-charged so there's no risk of damage or explosion from incorrect charging. Programmable charging process. Charging of each individual cell can be monitored on the LCD screen. Powered by mains plugpack or a 12V battery (or any other DC source from 10 - 18 volts). 132(L) x 82(W) x 28(H)mm.

BATTERY TESTERS

$13.95

DOUBLE POINTS

Battery, Bulb and Fuse Tester QP-2252

Tests AAA, AA, C, D (1.5V) & 9V batteries and indicates their power level. It checks bulbs and fuses, giving a 'good' or 'replace' indication, and will also test larger 1.5V button batteries like the LR-44. Requires 9V batteries.

Batteries not included

$23.95

DOUBLE POINTS

All in One Battery Tester QP-2253

Can test standard AA/AAA/C/D/9V batteries, button cells and lithium batteries such as those used in digital cameras.

BATTERY HOLDERS SEE THE WHOLE RANGE IN-STORE!

PH-9280

FROM 95¢

DOUBLE POINTS

AA Battery Holders

2XAA SIDE BY SIDE PH-9202 **$0.95**
2XAA SWITCHED BATTERY ENCLOSURE PH-9280 **$2.45**

PH-9260

FROM 80¢

DOUBLE POINTS

AAA Battery Holders

Moulded in Derlin with corrosive resistant nickel plated springs and studs

1 X AAA PH-9260 **$0.80**
2X AAA PH-9226 **$1.45**

SOLAR PANELS

Powertech Monocrystalline Solar Panels

The panels are fitted with a waterproof junction box, UV stabilized output cables and bypass diodes to withstand harsh environments.

12V 20W ZM-9094 **$69.95**
12V 40W ZM-9095 **$129**
12V 80W ZM-9097 **$269**
12V 120W ZM-9085 **$329**
12V 145W ZM-9087 **$399**
24V 200W ZM-9088 **$559**

25 YEAR WARRANTY (SEE T&C'S)

FROM $69.95

ZM-9097

ZM-9095

12V Semi-Flexible Solar Panels

These monocrystalline solar panels can be easily mounted on the curved surfaces of your boat deck or caravan to charge on-board batteries. The flexibility of the solar cells is limited by the plastic base but will easily bend on the long axis to accommodate a yacht deck or RV roof. It is slightly flexible on the short axis.

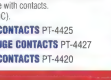
40W ZM-9152 **$199**
100W ZM-9154 **$429**
180W ZM-9156 **$749**

ZM-9152

FROM $199

HIGH CURRENT CONNECTORS

$9.95 ea


PT-4420

Anderson® 50A Power Connectors

Used widely in both domestic and industry, you'll find this connector in many 4WD applications, boating, automotive and other industries. Supplied as a moulded 2 pole with contacts. 50A, 600V (AC or DC).

WITH 8 GAUGE CONTACTS PT-4425
WITH 10-12 GAUGE CONTACTS PT-4427
WITH 6 GAUGE CONTACTS PT-4420

FROM $19.95

PT-4424

Anderson® 120A & 175A Power Connectors

Used widely in both domestic and industry. Supplied individually with a pair of contacts. 600V (AC or DC).

120A PT-4422 **$19.95**
175A PT-4424 **$29.95**

SOLAR CONNECTORS AND CRIMPS

VALUED AT $94.90

BUNDLE INCLUDES:

1X WATERPROOF SOLAR POWER "PV" CONNECTOR 4MM FEMALE PS-5100 **$7.50**
1X WATERPROOF SOLAR POWER "PV" CONNECTOR 4MM MALE PP-5102 **$7.50**
QUICK CHANGE RATCHET CRIMP TOOL TH-2000 **$49.95**
QUICK CHANGE CRIMP TOOL DIES - PV TO SUIT TH-2000 TH-2010 **$29.95**

ALSO AVAILABLE:
SOLAR SYSTEM CABLE FROM $4.20/M

NERD PERKS CLUB
BUNDLE $59.90
SAVE $35

SOLAR CHARGE REGULATORS / CONTROLLERS

FREE FUSE AND HOLDER FOR NERD PERKS CARD HOLDERS* SZ-2016 & SF-2200

SZ-2016 VALUED AT $3.50
SF-2200 VALUED AT $0.40

$29.95

12V 5A Battery Charging Regulator

FOR SOLAR PANELS AA-0348

Ideal for charging 12V SLA batteries from solar panels up to 60 watts. 5 amp fuse and fuseholder recommended - not supplied.

- <3.9mA (LEDs on) power consumption
- 72(W) x 50(D) x 43(H)mm

MP-3129

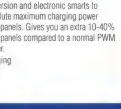
FROM $64.95

Solar Charge Controllers

This unit is capable of handling all of your solar charging requirements and protects your battery. It has an array of features including adjustable charging voltage, automatic dusk-till-dawn on/off, overload protection, etc.

See our website for details.

12V 8A WATERPROOF MP-3720 **$64.95**
12V 20A MP-3129 **$179**
24V 20A MP-3724 **$199**
12V 30A MP-3722 **$219**



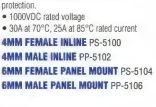
$259

12V/24V 30A MPPT Solar Charge Controller MP-3735

Maximum Power Point Tracking technology uses DC to DC conversion and electronic smarts to extract the absolute maximum charging power from your solar panels. Gives you an extra 10-40% from your solar panels compared to a normal PWM charge controller.

- 3-stage charging
- LCD display

SOLAR PANEL CONNECTORS - DOUBLE POINTS


PP-5106

DOUBLE POINTS

$7.50 ea

Waterproof Solar Power PV Connectors

IP67 rated for maximum environmental protection.

- 1000VDC rated voltage
- 30A at 70°C, 25A at 85°C rated current

4MM FEMALE INLINE PS-5100
4MM MALE INLINE PP-5102
6MM FEMALE PANEL MOUNT PS-5104
6MM MALE PANEL MOUNT PP-5106

DOUBLE POINTS FOR NERD PERKS CARD HOLDERS ON THESE SOLAR PANEL ACCESSORIES

240VAC High Current Circuit Breakers

DIN rail mounted circuit breakers suitable for solar applications. Electrical safety authority approved.

10A SINGLE POLE SF-4150
16A SINGLE POLE SF-4151
20A SINGLE POLE SF-4153
32A SINGLE POLE SF-4153

SF-4150

$4.95 ea

DOUBLE POINTS

DOUBLE POINTS

$79.95

Aluminium Solar Panel Angle Mounting Bracket HS-8785

Mounting a single solar panel allows you to tilt the panel to your desired angle.

- Holes pre-drilled to line up with 80W panels
- Supplied with full stainless steel hardware

SZ-2090

FROM $9.95

DOUBLE POINTS

Power Distribution Posts WITH BRIDGE PLATE

Heavy duty stainless steel posts mounted on a moulded plastic base.

SINGLE M10 SZ-2090 **$9.95**
TWIN M8 SZ-2092 **$11.95**
TWIN M6 POWER SZ-2094 **$11.95**

Solar Panel 'Y' Leads

2 PLUG TO 1 SOCKET

Used for connecting the output of two solar panels in parallel or connecting multiple panels in an array. Waterproof and UV resistant.

2 SOCKET TO 1 PLUG PS-5110
2 PLUGS TO 1 SOCKET PS-5112

$19.95 ea

PS-5110

DOUBLE POINTS

ARDUINO PROJECT FOR NERD PERKS CARD HOLDERS

SEE STEP-BY-STEP INSTRUCTIONS ON www.jaycar.com.au/diy-arduino-led-tester

Build Your Own Arduino® LED Tester

Features include:
- Adjustable test current.
- Displays LED Forward Operating voltage.
- Calculates ideal resistor & gives cat. number for a design voltage and current.
- Only 3 discrete components to be soldered.
- Detachable shields - pull it apart & use for other projects.

NERD PERKS OFFER
ADVANCED BUNDLE
$49.95
SAVE OVER $12

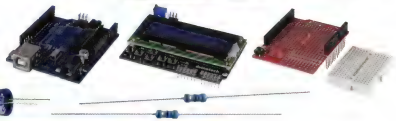
Completed project.

PROJECT BUNDLE:

VALUED AT $62.55

BUNDLE INCLUDES:

DUINOTECH CLASSIC (UNO) XC-4410 **$29.95**
ARDUINO® COMPATIBLE PROTOTYPING BOARD SHIELD XC-4482 **$15.95**
ARDUINO® COMPATIBLE 2 X 16 LCD CONTROLLER MODULE XC-4454 **$14.95**
100HM 1/2 WATT 1% METAL FILM RESISTORS - PK.8 RR-0538 **$0.55**
100HM 1/2 WATT 1% METAL FILM RESISTORS - PK.8 RR-0524 **$0.55**
470UF 16V RB ELECTROLYTIC CAPACITOR RE-6194 **$0.60**



ACCESSORIES TO USE WITH DUINOTECH CLASSIC (UNO)

$7.95

Arduino® Compatible DC - DC Stepdown Module XC-4514

This moduleaccepts any voltage from 4.5 - 35VDC, and outputs any lower voltage from 3-34V.Output is adjusted via a multi-turn potentiometer. Use it to run your 5VDuinotech projects from a 6v, 9v or even 12v Supply.

$19.95

Arduino® Compatible RF Transceiver Module XC-4522

This module adds a versatile 433MHz radio to your Duinotech project allowing two-way wireless communication between Duinotechs. Controlled via SPI. Prewritten libraries available.
- Includes antenna
- 32(W) x 19(L) x 19(H)mm (Excluding antenna)

$47.95

LeoStick XC-4266

A tiny board small enough to plug straight to the USB port without requiring a cable. Features ATmega32u4 MCU with 2.5K RAM and 32K Flash.
- Analogue & digital I/O
- User-controlled RGB LED
- 9(W) x 19(H) x 8(D)mm

ALSO AVAILABLE:

LEOSTICK PROTOTYPING SHIELD
XC-4268 **$9.95**

$29.95

DuinoTECH Classic (UNO)

XC-4410

ATMega328P Microcontroller. Powered from 7-12VDC or from your computers USB port. 5VDC Regulated via USB port or 5V pin.
- 75(W) x 53(L) x 13(H)mm

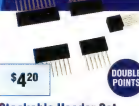
ARDUINO® KITS

$109

Arduino® Experimenters Kit

XC-4262

Learn about the exciting world of Arduino® with these easy to build projects. From flashing LED to moving things with a servo. Complete with instructions and a supporting web page and software examples. No soldering required.



$4.20

DOUBLE POINTS

Stackable Header Set

HM-3207

The perfect accessory to the ProtoShields and vero type boards when connecting to your Arduino® compatible project.
- 1 x 10-pin
- 2 x 8-pin
- 1 x 6-pin
- 1 x 2x3-pin (for ICSP)

$16.95

DOUBLE POINTS

Resistor Pack

300-PIECES RR-0680

This assorted pack contains 5 of virtually each value from 10Ω to 1MΩ.
- 0.5W 1% mini size metal film

See website for full contents.

$34.95

DOUBLE POINTS

Light Duty Hook-up Wire Pack

8 COLOURS WH-3009

Quality tinned hook-up wire on plastic spools. 8 rolls included, each roll a different colour.
- 25m on each roll

$129

Deluxe Modules Package

XC-4288

Get more savings by purchasing this 37 modules-in-1 pack. Includes commonly used sensors and modules for duinotech and Arduino® joystick, magnetic, temperature, IR, LED and more.

DOUBLE POINTS

Light Dependent Resistor (LDR)

Cadmium Sulphide (CdS) light dependent resistor cells suitable for all your light-sensitive projects.

2.8K OHM TO 8.4K OHM
RD-3485

48K OHM TO 140K OHM
RD-3480

$3.25 ea

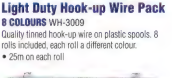
$4.50

DOUBLE POINTS

Economy Breadboard Jumper Kit 5 COLOURS WH-3032

Solid core hookup cable, which is the ideal size for breadboards. All you need to do is cut it to whatever lengths you require and strip the ends.
- Includes 2m of each colour

Colours may vary from time to time.



$13.50

DOUBLE POINTS

Breadboard Jumper Kit

PB-8850

This kit consists of 70 pcs of single core sturdy wire which has been stripped on each end and bent at right angles. They are specifically made for breadboards. Supplied in a plastic box for easy storage. There are 5 pieces each of 14 different lengths.

ARDUINO® COMPATIBLE MODULES AND SHIELDS

$3.95

Arduino® Compatible Infrared Receiver Module XC-4427

Receive data sent via infrared, this module can read the signals sent by most IR remote control/s.

- Operating Voltage: 5VDC
- 28(L) x 15(W) x 2(H)mm

$5.95

Arduino® Compatible Temperature Sensor Module XC-4494

This module provides a simple way to measure temperature. The module outputs an analog voltage that varies directly with temperature. Connect it straight to one of your DuinoTECH analog inputs.

- Operating voltage: 5VDC
- Max 100°C
- 21cm Breakout cable included
- 33(W) x 22(D) x 9(H)mm

$7.95

Arduino® Compatible Line Trace Sensor Module XC-4474

This module measures the reflectivity of a surface with an infrared emitter/detector pair. The output goes to high whenever the reflectivity exceeds the threshold value, which can be adjusted with the onboard potentiometer.

- Output electrical level signal: Active Low
- VCC/OUT/GND pin connector
- Power Supply: 2.5-12V
- Working current: 18-20mA at 5V

$19.95

Arduino® Compatible Temperature Sensor Module XC-4538

This versatile 1-wire bus temperature sensor module features 0.5°C accuracy and fast response, and is easy to connect up for all projects. Perfect for building your temperature-sensitive projects or even add on to your home automation system or datalloggers. Temperature Range: -55°C - +125 °C

- 20(W) x 15(L) x 5(H)mm

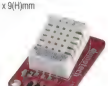
Limited stock. Not available online.

$7.95

Arduino® Compatible Microphone Sound Sensor Module XC-4438

Our range would not be complete without a microphone sensor module. This unit is highly sensitive with the added advantage of having two outputs. An analogue output for real time microphone voltage signal, and a digital output for when the sound intensity reaches its threshold. Great to turn your Arduino® into a voice recorder or vox.

- 5VDC operational voltage
- Sensitivity potentiometer adjustment
- 43(L) x 16(W) x 13(H)mm



$19.95

Arduino® Compatible Temperature Sensor Module XC-4432

Measure both temperature and humidity with this nifty module. Full digital operation so no analog to digital calibration is required.

- Temperature Range: -40 °C - 80 °C +/- 0.5 °C
- Humidity Range: 20 – 90% +/- 2%
- Sample Rate: 0.5Hz
- 52(W) x 20(L) x 13(H)mm

Limited stock: Not available online.

$44.95

Arduino® Compatible 8 x 8 RGB LED Matrix Driver Module XC-4498

A full colour RGB display driver designed to drive a tri-colour 8x8 dot matrix. Drivers by an ATMega328p (The same chip as the Arduino®), this module communicates with your project via I2C. Alternatively, use an ICSP programmer (XC-4237) to flash your own firmware and the device no longer requires an external controller.

- Operating Voltage: 5VDC
- 66(L) x 60(W) x 12(H)mm

$119

3.2" LCD Touchscreen Display Kit FOR ARDUINO® XC-4280

Add an interactive touchscreen display to your existing Arduino® projects. Draw lines, shapes, text, display images, play sound and log data to microSD card. Includes LCD display, 40 Arduino® Adaptor Shield, 5-way interface cable and USB programming adaptor with pre-loaded software.

- Operating voltage: 4.5 - 5.5VDC
- Screen display area: 64.8 x 48.6mm
- Screen resolution: 240 x 320 pixels
- 65K True to life colours

Limited stock. Not available online.

$4.95

Arduino® Compatible Amplifier Module XC-4448

This remarkably small module provides a complete 2 x 3W stereo audio amplifier. Ideal for driving small speakers and earphones. Requires no external components.

- Operating Voltage: 2.5-5.5VDC
- 23(W) x 16(D) x 2(H)mm

$4.95

Arduino® Compatible Logic Level Converter Module XC-4486

It provides two bi-directional channels to safely marry 3.3V with 5.0V. Drops straight into solder-less breadboard or can be soldered into your own PCBs.

- Two bi-directional channels
- 12-pin DIL package
- 35(W) x 31(D) x 21(H)mm

$9.95

Arduino® Compatible 3 Axis Compass Magnetometer Module XC-4496

This module allows you to take accurate compass bearings, no matter how it is orientated. Easily interfaced via I2C.

- Operating Voltage: 5VDC
- Resolution: 12bits
- Includes 5V - 3V level shifter.
- 20(L) x 16(H) x 5(H)mm

$119

RGB LED Cube Kit 4x4x4 FOR ARDUINO® XC-4274

This stunning 3D-matrix of 64 RGB LEDs connects directly to your Arduino®-compatible board so you can produce mesmerising light shows controlled by software.

- 4x4x4 matrix of individually addressable 8mm RGB LEDs
- 106(W) x 130(H) x 106(D)mm (assembled)

PRE-ASSEMBLED MODULES

$9.95

Multi-Voltage Regulator 1.5A AA-0372

This module is a low-powered DC converter for many applications. Just plug its input into your PC's internal power supply cable and get selectable regulated voltage out from 3 to 15VDC*. Output current capability is around 1.5 amps.

- 63(L) x 24(Dia.)mm

AA-0223

$24.95 ea

Universal Amplifier Modules 1 CHANNEL

Ideal as a bench-test amplifier for audio sources, or even as a mono headphone amplifier, this small audio amplifier can be operated from 4.5 V up to 12 VDC. Use two for stereo.

3.5W AA-0223

12W AA-0225

$29.95

24-12V 3A Converter Module M038 AA-0266

Many trucks and boats use 24V systems. These converters will allow you to run a reasonably sized 12V car-stereo or other devices from a 24V supply. Heatsink (not included) should be used for superior performance. Features include: short-circuit protection and thermal cut-out.

- 90 x 60 x 34 mm

$37.95

12V 3A Timer Module 2 SECONDS TO 23 MINUTES AA-0364

A versatile and useful timer module that can be set for periods of 2 seconds to 23 minutes. The start and stop functions are controlled by simple switch inputs and the relay output can control a device of up to 25VDC at 3A.

- Operating voltage: 12-15VDC
- 87(L) x 60(W) x 30(H)mm

CLEARANCE SAVE UP TO 50%

Magnetic Reed Switch Module

XC-4476 **WAS $7.95**

A simple to use reed switch module, output will turn whenever the reed switch is in proximity to a magnetic field. Useful for door security.
Operating voltage 3-5VDC

- Digital output
- 16mA comparator output capacity
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Limited stock.

SPECIAL $4.75 SAVE 40%

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SB-2303 **WAS $9.95**

Universal Lithium-ION "14500" size battery. 3.7V 750mAh. Similar in size to an AA battery. Suitable for LED torches and other applications.

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XC-5074 **WAS $24.95**

This device displays the voltage and current that your USB powered device uses.

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- Safety approval number: N13057

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WITH NIGHT LIGHT PP-4039 **WAS $9.95**

Leave a night light on without wasting a power point. Light sensor for automatic on/off.

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Ni-Cd & Ni-MHRecharge up to 4 x AA, AAA, C, D and 2 x 9V Ni-Cd or Ni-MH batteries together for a total of 6 batteries. Using Delta V voltage detection and cut-off, batteries are never overcharge. With LCD display.

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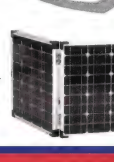

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Limited stock.

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PRODUCT SHOWCASE

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SERVICEMAN'S LOG

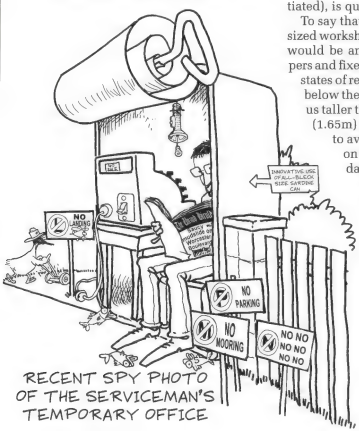
Sorting my quake-damaged workshop

Dave Thompson*

I absolutely love test equipment and have recently been given some very nice test gear by a friend who's just retired. Fortunately, I now have somewhere to stash this gear, having just got my quake-damaged workshop properly sorted out and functioning again.

ONE THING that makes being a serviceman so much fun is that we get to have a cool workshop to hang out in. There are as many different workshops as there are servicemen and I always find it fascinating to take a look at the workshops of other people I meet in the industry.

I especially like to check out what tools and gadgets they have, to find out whether similar tools could be used in my workshop to make my job easier (or would just be cool to have).



RECENT SPY PHOTO OF THE SERVICEMAN'S TEMPORARY OFFICE

A good friend of mine, who was involved in 2-way radios, has just retired and he and his wife are now looking to down-size the family home into something more manageable for a retired couple. And that means he must clear out his workshop.

His man-cave is a particularly interesting place for me to visit. His hobbies have involved all things to do with radio and his collection of radio-controlled aircraft, especially rotary-wing models (helicopters to the uninitiated), is quite impressive.

To say that this guy's single-garage-sized workshop is packed to the rafters would be an understatement. Choppers and fixed-wing models in various states of repair hang both above and below the rafters, requiring those of us taller than about 5-feet 5-inches (1.65m) to walk slightly stooped to avoid taking out an eye out on an errant skid or a piece damaged landing gear.

The floor is covered with pretty much the same blend of models, half-built kit-sets and associated gear.

All that's left uncovered is a well-beaten path from the door to the light-switch and to the equally-cluttered workbench. The single light bulb (an energy-saver that takes 10 minutes to warm up) casts a yellow glow over the scene and this and the associated shadows add to the atmosphere.

It's no exaggeration to say that I love it there and I'll be very sad when he down-sizes to some tiny shed that I guarantee won't have anything like the feel of this haven.

However, there is a silver lining; Keith has had to get rid of his old scopes, frequency counters and other flashing-light-infested test gear and, in the spirit of friendship, he kindly offered to give some of these instruments to me. The deal is that I can be their guardian for as long as I want them and for as long as he can come over and use them if he ever needs to. Since he hasn't used some of them for a few years now, it's unlikely he'll ever take me up on that but that's OK; I'm happy for him to come and use my facilities any time he likes.

So far, I have been given a digital oscilloscope (an older, 60MHz dual-channel monochrome model) and a top-quality 20MHz CRT scope, both of which are in excellent working order. They really do look great on my shelf along with my existing scope and various multimeters, soldering stations and power supplies.

I admit it; I love test equipment and if I won the lottery I'd have the best spectrum analysers, audio generators,

Items Covered This Month

- Dave finally gets his workshop functioning again
- Faulty Sunbeam Retro KE52-00E kettle
- Deckel FP4 CNC milling machine
- Maison vacuum cleaner
- Faulty Zen-on Justina guitar tuner

Dave Thompson runs PC Anytime in Christchurch, NZ.
Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

frequency counters and all manner of other suitably-adorned boxes stacked from bench-top to ceiling. The beauty of having this equipment is learning how to use it to better do my job and enjoy my hobby, the two curiously crossing over more often these days. I've already put the scopes to good use and I'm now looking forward to taking possession of a very nice AF/RF frequency generator/counter that's next on the list to go from Keith's workshop.

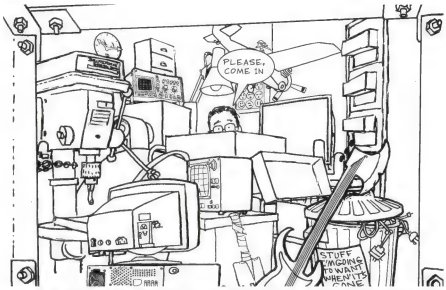
Quake-damaged workshop

Some years ago, my own workshop, which is about double-garage sized, was rendered a complete disaster area by the swarms of quakes we had here in Christchurch five years ago. Prior to those cursed quakes, I had a lot of stuff neatly set up in cupboards, on shelves and in drawers and other storage units all around the walls of my workshop. This "stuff" included small bucket-sized bins of resistors, capacitors, diodes, transistors, ICs and other components one tends to accumulate over 40 years of hobby and professional electronics work.

These parts were all neatly arranged and stored in their own compartments and trays until 12.51PM on the 22nd February, 2011, wherein the shelves, drawers and cupboards were literally torn from the walls and everything in and on them ended up dumped onto the workbenches and floor below. The benches run around the entire workshop at a height of 900mm, with gaps only for the entry door and a couple of larger machines along the back wall.

During the subsequent aftershocks, of which there were many, everything else that lived in racks, drawers, shelves and boxes under, on or around the benches also ended up on the floor, along with my lathe, drill-press, sander, band-saw, scroll-saw and electronic test gear.

I almost cried when I first opened the door but soon forgot about that because my lathe had fallen across the doorway, preventing it from opening properly. The lathe had also taken out a tall metal cabinet of drawers that lived next to it. Fortunately, all the drawers (A4-sized and full of lathe tools, components, half-finished projects and other electronic bric-a-brac) had fired out into the middle of the room, so they avoided getting crushed. However, their contents added to the pile that now covered most of the workshop floor.



THE BEST THING ABOUT IT IS THAT IT'S A PROPER WORKSHOP AGAIN & I'M NOT EMBARRASSED TO SHOW PEOPLE AROUND WITHOUT MAKING LAME EXCUSES...

I initially surveyed the damage through the gap in the door and after checking nothing was on fire and that the workshop power was disconnected (fortunately, the mains were off and would stay off for another 20-odd hours), I locked the door and vowed to sort it all out later.

It took about a year to get the workshop into some semblance of order, which basically meant I could walk around most of it. It was still a right mess though and remained like that for another few years as our focus was on other things. Besides, with on-going after-shocks, there was an air of "why bother?" about it all. It was a terrifying time and I didn't want my epitaph to read: buried in his workshop!

As a result, my workshop space became a little-utilised repository for anything that didn't fit in the house, or was too valuable to leave in the often-open garage that fronted the workshop itself. My workbenches, which had been clear and organised, were now covered entirely in stuff and if I wanted to do anything, I had to literally push things aside until I had room for the new job.

Over the years, I chipped away at clearing it up by doing things like sorting out the resistors from the capacitors and then separating other components – no easy task when literally thousands had been mixed together into a scrambled and hard-to-pull-apart pile that would likely have filled a bathtub. Part of me wanted to just toss the lot and start again but the miser in me prevented me from tossing perfectly good components.

It took quite some time to sort it all out and I while I was at it I also separated the electrolytics and tantalums from the non-polarised capacitors and sorted miscellaneous items like terminals from screws, nuts and bolts. One of the most frustrating jobs involved separating about 200 assorted springs from all the other bits; they gripped and grabbed onto everything and I very nearly just chucked the lot but decided against it after considering how long it took me to accumulate them (and how handy they can be).

Once I had all that small stuff squared away, I began looking at shelving and other storage options that wouldn't be susceptible to falling down in quakes. A lot of bits and pieces originally lived on shelves around the walls but I now had to find homes for them in drawers and other solid storage options.

We haven't had any sizable aftershocks for the last 12 months (touch wood) but I'm reasonably confident the storage I now have will take anything up to and including a quake that would drop the garage. And if that happened, I'd have bigger problems than sorting out some resistors!

At least we don't have to worry about bushfires, which would be absolutely terrible. Give me a quake any day over fires (well, a smaller jolt at least).

To chuck or not to chuck

Over the recent Christmas break, I

Deckel FP4 CNC milling machine

D. A. of Shepparton, Victoria recently encountered a string of faults in an old Deckel FP4 CNC milling machine. Here's how he got it going again . . .

Earlier this year, I was asked by a relative if I'd have a look at one of his CNC milling machines. The machine in question was a Deckel FP4 unit from the mid-late 1980s and it had developed a fault in the CNC console. I'm no expert when it comes to engineering but I've spent many years repairing electronic/electrical and mechanical equipment, both as a career and as a hobby, and so I thought "why not?".

CNC stands for "computer numerical control" and a CNC mill/lathe has a computer console which allows the user to push buttons and enter commands to drive the machine's servos and motors. These in turn control the movement of various tools and/or the job itself in the machine to achieve the desired cutting and turning, etc.

The story starts when the machine began displaying an FP00 error code which, according to the manual, indicates an emergency shut-down, tripped overloads and/or pressed emergency stop buttons. The first step then is to check the overloads and emergency stops and in fact the owner had already done this but had found nothing amiss.

My first thought was that a power supply fuse had probably blown or the supply itself was faulty. When I took a look inside, I found that a fuse had indeed blown. I replaced it and the console came back to life but there was no vertical sync, thus causing the picture to roll continuously. However, I was told that the vertical rolling fault had been there for some time and that the picture stopped rolling after the machine had warmed up. And indeed that turned out to be the case.

What was encouraging was that there was no longer an FP00 error on the display. However, the unit still refused to work.

Thankfully, the owner has the operator's manual and the service manual for the machine. Unfortunately, the service manual is printed in German (since the machine is German-made) so I spent quite some time going over the circuits diagrams and checking for continuity in the emergency stop circuit. Eventually, I found that a track on the circuit board had been burnt off.

Fixing this cured the fault with the emergency stop circuit and the machine worked again. However, I was puzzled as to what had caused the fault, as it appeared that the circuit board track damage would have been caused by an inadvertent short.

The next day, the FP00 error was back so I again checked the emergency stop circuit and found that it was functioning as intended. The FP00 fault code can also mean that one of a few overload circuit breakers had tripped, so I now turned my attention to those. These were all intact so I consulted the circuit diagrams and after some time found that these overload circuit breakers are 3-phase with an auxiliary contact. This auxiliary contact is used to relay the fact that one of the circuit breakers has tripped, thereby halting the machine and bringing up the FP00 code.

I soon found that one of the wires going to one of the auxiliary contact's terminals had been clamped mostly on the insulation rather than on the copper wire and a quick check with a multimeter confirmed no continuity. I re-terminated it and the problem was solved. This was probably a manufacturing defect, the wire just touching the terminal for all those years before it finally went open circuit.

In the end, it was a very simple fault but it wasn't easy to find. Of course, that left the vertical rolling fault but because it quickly disappeared as the machine warmed up, we decided to leave it for the time being.

That situation didn't last long because as winter came on, the vertical rolling fault got progressively worse. Eventually, it was taking around five hours for the display to stop rolling after the machine had been switched on.

Having worked on many CRT TV sets, I was fairly sure that this wouldn't just involve adjusting the internal vertical hold control. Instead, the nature of the fault suggested component drift and I suspected faulty electrolytic capacitors due to the age of the unit.

Armed with the circuit and an ESR meter, I checked all the electrolytic capacitors on the deflection/HV circuit board. Most of them measured open-circuit which wasn't surprising after 30 years or so of service.

I replaced the lot, then reassembled the console and switched the unit on. The picture was now locked solid and that finally cured the annoying rolling problem.

That wasn't to be the end of the sto-

finally got onto the home straight with the workshop. I spent around three hours each day that I was off work sorting out what I wanted to keep and what I wanted to chuck.

I've mentioned before that while I'm not a pack-rat, I do tend to gather items that could come in useful for my servicing work. However, I had to modify my philosophy with this clean up. My criteria before starting the clean-up was: will I conceivably ever use this item; yes or no? If "no", the item went into a rubbish box.

I also asked "do I really need this item"? Again, if the answer was no, the article went straight into the bin.

It was actually quite liberating to get rid of the junk and tidy the workshop; I'd had some of that stuff for so long and the workshop had been such a mess that it hung over me like a black cloud and I dreaded going in there. In fact, there's a book currently sweeping the USA about the very subject of getting rid of unwanted clutter and how life-affirming it can be.

In this book, the author poses the question: does this item "spark joy" in my life? If it doesn't, out it goes. While I liked my criteria a little better and thought it a little more practical, it was interesting that I had much the same experience while cleaning out my workshop that this person wrote about. At the same time, I quietly

ry though. A couple of days passed and, much to my frustration, the Deckel FP4 again had a problem. This time, it was tripping one of its overload circuit breakers as soon as there was any attempt to start the hydraulic pump motor. Apparently, this machine uses hydraulics to actuate some of the bed axis movements but I'm no expert on how the whole machine works.

In this case, an FP02 error code was appearing on the console. The manual was quite helpful here because it stated that an FP02 error code meant hydraulic pump overload and this indicated the relevant overload breaker to check. It was tripping the overload at switch-on alright and my first thought was that the pump/motor may have seized or something along those lines.

The only other option would be a power issue. Sure enough, when I checked the mains voltage on each phase at the overload circuit breaker with respect to ground, two phases were at 230VAC while the centre measured just 63VAC. Three-phase motors don't appreciate a missing phase and will draw lots of current and generally refuse to start.

I then did the same measurements at the 3-phase power point for this machine only to find the same readings. So we had a power issue, rather that a fault in the machine itself.

When I inspected the main switchboard, I discovered that the machine was on a circuit with individual phase fuses rather than a 3-phase "ganged" circuit breaker. In the end, it was a simple case of removing the blown centre fuse and replacing it. Once all three phases had been restored, the old Deckel CNC machine operated normally once more and should live on for many more years.

cursed the fact that I hadn't thought about writing a book about it. It could have made millions of dollars, which of course would enable me to buy even more stuff to fill my workshop with! Perhaps it all worked out OK after all . . .

After dumping/recycling 350-odd kilograms of rubbish from the workshop, I had a lot of spare space left over. It now feels great to be able to walk to any part of the bench and have room to work on it without having to move stuff around. The best thing about it is that it's a proper workshop again and I'm not embarrassed to show people around without making lame excuses as to why it was such a bomb-site. While I could legitimately claim it was caused by something beyond my control, it certainly wasn't beyond my control to tidy it properly long before now.

Of course, it didn't take long for someone to ask me if I had something that I'd just chucked away! It had been in my workshop for years but hadn't met my criteria for keeping it. The fact is, this will happen every so often and I'll just have to live with it.

The kettle carks it

Another thing I'd gotten rid of was a kettle we'd replaced a few years ago with a nice new "digital" model. There was nothing wrong with the old one; it just didn't colour-match our new toaster so, of course, it had to go. And so, after all those years in the workshop, out it went to the recycling station, no doubt to eventually turn up in one of those eco-shops for a few dollars.

I mention this now because just the other day Nina pushed the power button on our kettle to boil some water. As she did so, it gave a nasty electrical "pop!" and its LED display went dead. And so, being a serviceman, the first thing I did was grab it and withdraw to my now-tidy workshop to find out what was wrong with it.

"It's probably just a fuse or something just as simple," I said to Nina as I made off with it. Yeah, right – famous last words, as many servicemen will no doubt confirm.

After negotiating the usual annoying security-type screws and removing the base of the kettle, the electronic gubbins were revealed. No simple switch, thermostat and element for this kettle; instead, inside was a PCB assembly that wouldn't look out of place in a GPS unit or a portable radio.

The top side of the PCB carried a number of parts and a 28-pin IC, most likely a microcontroller of some description. This side appeared to be OK, so I then had to remove quite a bit of plastic mounting hardware and unplug various peripherals such as thermostats, wiring looms for the display and the element wiring in order to gain access to the underside of the PCB.

As soon as I flipped it over, the cause of the "pop" was all too obvious; four

very blackened surface-mounted diodes and at least one transistor (or similar SOT-23 type component) were clearly damaged. A quick search with Google confirmed my assumption that there would be nothing like a circuit diagram floating around for this appliance and with all active components sanded or with their part numbers otherwise obfuscated (thanks manufacturer), this was likely going to be another guesswork fix.

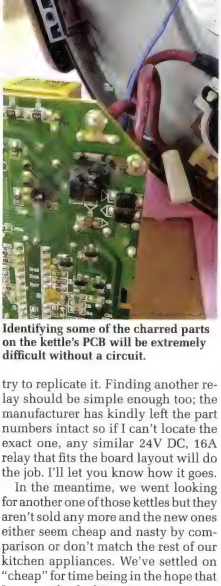
And so, for the time being, I'm stumped. If anyone out there in Silicon Chip "reader-land" has a circuit diagram for a Sunbeam Retro KE5200E kettle and is willing to share it, please contact me.

The rest of the board appears to be in pristine condition, probably because the whole thing is covered in some sort of soft, clear "goop" to waterproof it. This goop had melted away from the dead components, making it easy to access them, but I suppose any "fix" will require a similar covering once done. I'll use epoxy resin. I think – should I succeed in getting it going again, that is . . .

All the failed components surround a relay whose contacts switch mains-level voltage to the element, so I'm wondering if the relay has shorted or something similar. The output track of this relay has been damaged so it'll have to be replaced too.

The diodes shouldn't be a problem; the silk-screen at least is very clear as to polarities etc and they look like 1N4001s or similar for rectifying AC to DC for the rest of the circuit. The SOT-23 "transistor" may be a regulator and if I can't get a diagram, I'll try to "reverse engineer" this part of the circuit and draw a diagram.

That way, I might be able to figure out what this part does, so that I can



Identifying some of the charred parts on the kettle's PCB will be extremely difficult without a circuit.

try to replicate it. Finding another relay should be simple enough too; the manufacturer has kindly left the part numbers intact so if I can't locate the exact one, any similar 24V DC, 16A relay that fits the board layout will do the job. I'll let you know how it goes.

In the meantime, we went looking for another one of those kettles but they aren't sold any more and the new ones either seem cheap and nasty by comparison or don't match the rest of our kitchen appliances. We've settled on "cheap" for time being in the hope that I can get the faulty unit going again.

But whatever happens, at least I've once again got a pristine workshop in which to work. It really is a much more pleasant place to be than before the big clean-up.

Maison vacuum cleaner

Regular contributor B. P. of Dundathu, Qld has no particular love for vacuum cleaners. But why chuck out old faithful when you can fix it yourself and save money into the bargain? Here's his story . . . .

Our middle (teenage) son had been doing some vacuuming (yes, really!) when the machine suddenly started making a loud rumbling noise. Not wanting to risk further damage, he turned it off straightaway and I decided to check out what the problem could be.

My first test was to turn the vacuum cleaner on and then off again quickly, so that I could briefly hear it running. We've had this vacuum cleaner for quite a long time and I had already repaired it several times previously. I'd also fitted new brushes to it around 18 months ago.

This time, however, I wasn't sure if it was repairable, because it sounded like the bearings were shot. The brushes were also arcing badly, which could indicate that the armature had shorted turns. Despite this, I decided to delve deeper and find out just exactly what the problem was.

I started by dismantling it and I initially checked the brushes. My suspicion was that they may have been poor quality and had worn down already, as the cleaner had had a lot of use since I fitted them. However, they were fine, with plenty of "meat" left on each one.

I then noticed that the rear bearing next to the commutator had blue marks on it, indicating that it had been running very hot. This wasn't looking good!

After some further dismantling, I had the armature free and I could then assess the situation more thoroughly. This revealed that the rear bearing had virtually disintegrated – the plastic retainer that keeps the ball bearings correctly spaced was no longer present, the metal shield on one side had fallen off and the rubber seal on the other side had also fallen off.

At that point, the bearing literally fell apart and the ball bearings dropped onto the ground. I also noticed that the metal shield had been distorted, which indicated that the bearing had been running out of true. Because the armature would have been moving around so much, this could explain why there had been arcing on the brushes.

I then checked the front bearing and found that it was only slightly worn. Even so, I decided that I would replace both bearings and this is where I ran into difficulty. My automotive bearing puller was just too big to remove the front bearing and it would not grip the inner race of the rear bearing.

As a result, I decided to reassemble the rear bearing, so that it would have a larger area for the bearing puller to grip. I retrieved the ball bearings, greased them and placed them in the outer race, then put the inner race back in. After turning the bearing, the individual ball bearings distributed evenly around the unit and I was able to use the bearing puller to remove it.

That done, I turned my attention to the front bearing. After some thought, I decided that because it wasn't badly worn and because I couldn't easily remove it, I would simply service it and leave it in place. First, I removed the outer metal shield to access the inside of the bearing. It had some dirt in it and the balls were devoid of grease, so I cleaned it using a pressure-pack can of multi-purpose spray and then blew out the remaining liquid with an air-compressor. I then searched for some suitable grease.

Because I do my own vehicle and equipment servicing, I have a variety of greases on hand. In the end, I chose some automotive "no melt" disc brake wheel-bearing grease, as this would be ideal for the purpose. After greasing the bearing, I refitted the metal shield and then noticed that there was some wear on the commutator. This was fixed by "dressing" it with a fine file.

I knew the rear bearing would be under $10, so it was worth taking a risk and replacing it. As it turned out, it cost less than $5 from a local supplier. Once I got it home, I set about re-assembling the vacuum cleaner and when I had the motor back together and in place, I decided to give it a run before re-fitting the cover.

When I turned it on, it ran smoothly without the rumbling noise but there was considerable arcing from the brushes. I was begining to think that the motor might be on the way out when it suddenly picked up speed. At the same time, the whine it made increased in pitch and it sounded "smoother".

When I looked at it, I immediately noticed that there was no further arcing from the brushes and it was running nicely. I can only assume that the initial arcing had been caused while the brushes "bedded in" again.

Who knows how much longer it will continue working but while ever I can continue to repair it and keep it going, I will do so. This repair cost less than $5

and saved yet another defective piece of equipment from going unnecessarily into landfill.

Of course, this type of repair would not have been taken on by a service agency. The cost of the labour alone would have comfortably exceeded the price of a new vacuum cleaner. It's really handy to be able to do this type of repair myself and save our family quite a bit of cash in the process.

Faulty guitar tuner

A. C. of Clarement, Tasmania recently repaired an ancient guitar tuner that had no less than three faults. Here's how he got it going again . . .

One of the challenges of being someone who "knows about" electronics is that all your friends and associates know you're the guy to send their paraphernalia to for a quick check-over when it's not working.

Recently, I was handed a cheap guitar tuner from my wife's employer ("your husband can fix stuff, right?") with the highly-detailed diagnosis that it was dead. The unit turned out to be a Zen-on Justina Quartz Guitar Tuner, with a 3-position switch to power the unit and check the battery level, a 6-position switch to select one of six string pitches, a moving coil meter to indicate the battery level and tuning of the guitar, a built-in mic to allow tuning acoustic instruments and a 1/4-inch socket on the side to accept a connection from an electric instrument.

The case was made of plastic in a garish 1970s orange colour but despite its apparent age, it looked to be in pretty good shape. In fact, the Justina reminded me of my first guitar tuner which had been given to me for Christmas about 25 years prior. Its familiar control layout suggested that it was some kind of generic design that had been produced over the years as a budget alternative to the more expensive tuners made by companies such as Boss and Peterson.

After sliding off the 9V battery cover it was a no-brainer to work out why the unit was dead. The battery clip was missing, with only the red and black wire entrails hanging out of the compartment. This was going to be easy!

I rifled through my parts drawers and extracted a 9V battery clip of a vintage that complemented the retro orange duco, de-soldered the two wires from the PCB and refitted the new clip in their place. I then managed to find a 9V battery with enough zing in it to pass the lick test and clipped it into the tuner.

Flipping the unit back over, I moved the first switch to the BAT position and was encouraged to see the needle rising to the lower end of the "Good" mark on the meter. I then slid the switch to the ON position, selected the A-string pitch and did my best impersonation of a chorister at what I thought was about 440Hz, but the meter's pointer failed to rise off the lefthand end-stop.

My first reaction was that the tuner was simply being judgemental about my dulcet tones, so I tried a few different pitches on the pitch selector switch, again with no success. I then connected a guitar to the 1/4-inch input socket but this also failed to elicit a response and after confirming that both the cable and the guitar were OK on a known-good tuner, I realised that it wasn't my singing that was the problem!

I opened the case again and had a careful look for any dry solder joints. This quickly revealed a fractured joint on the 1/4-inch socket and I surmised that both the microphone and guitar signals passed through this socket, with the microphone signal being bypassed when a guitar was connected. After re-soldering this joint, I turned the unit back on and checked the response with my voice and a guitar but the meter still refused to move.

Disassembling the tuner for a third time, I re-inspected the PCB for any further dry joints that I may have missed. I found a couple of narrowly-spaced pads near the new battery clip pads that looked a little frosty but I didn't think they were bad enough to cause trouble. Even so, I re-flowed these pads with fresh solder as well.

Curious to know what was on the other side of the board, I flipped it over and had a look at the device connected to the pads I had just re-flowed. It turned out to be a 78L05 5V regulator but there appeared to be some kind of strange mark on the front of its body. On taking a closer look, I realised that the mark was in fact a crack that had split the regulator right down the middle.

I duly replaced the damaged regulator and reassembled the guitar tuner for what I hoped would be the last time. And that was it – this time, when I connected a guitar, I was at last rewarded with the pointer springing up to the middle of the dial when I ran the pitch tests. A quick whistle test confirmed that the microphone also worked. It also confirmed that my initial assessment of my vocal abilities wasn't too far off the mark.

I can't imagine what caused the 78L05 to fail in such a spectacular way considering that the highest voltage applied to it would have only been from a 9V battery. As can be imagined, the owner was grateful to have the tuner back in working order. SC

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

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Solar MPPT Charger & Lighting Controller

Our new Solar MPPT Charger/Lighting Controller uses solar panels to charge a 12V or 24V battery and then works with LDR/PIR sensors to run 12V DC lighting or an inverter. Last month, we gave the circuit details; this month, we show you how to build it and describe the setting-up procedure.

Pt.2: By JOHN CLARKE

THIS UNIT is easy to build, with all parts mounted on a PCB coded 16101161 and measuring 141 x 112mm. This is mounted in a diecast case measuring 171 x 121 x 55mm. The PCB is secured to integral mounting points inside the case and is shaped so that it fits neatly around the central pillars on either side.

As well as providing a rugged assembly, the diecast case also provides heatsinking for diodes D1 & D2, power Mosfet Q1 and power transistor Q3.

Fig.7 shows the parts layout on the PCB. Begin the assembly by installing the resistors. Table 1 shows the resistor colour codes but you should also use a DMM to check each value as it is installed, as the colours can sometimes be hard to decipher. Note that the "in brackets" values shown for some of the resistors are for the 24V version of the Solar Charge & Lighting Controller.

Note also that the 0.01Ω 3W resistor (just above fuse F1) should be left out at this stage of the assembly. It goes in after the fuse clips have been installed (see below).

Diode D3 can go in next, followed by zener diodes ZD1, ZD2 & ZD3. These must all be mounted with the correct orientation, as shown on Fig.7. Leave power diodes D1 and D2 out for the time being.

Zener diode ZD4 is not normally installed and a wire link is used for resistor R2. This is the standard set-up if using a PIR sensor that can handle a supply of up to 14.4V.

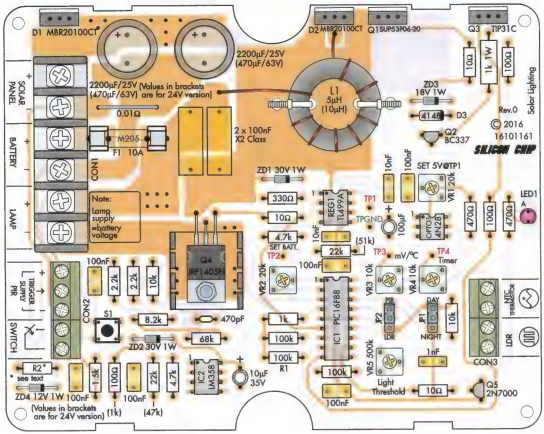


Fig.7: follow this parts layout diagram to assemble the PCB. Power devices D1, D2, Q1 & Q3 must all be mounted on 10mm lead lengths, while LED1 is mounted on 20mm lead lengths so that it can later be bent over to protrude through the side of the case. Refer to the text for the winding details for inductor L1.

Conversely, ZD4 must be installed if you are using a PIR sensor that's rated at 12V maximum. If ZD4 is fitted, you must also use a resistor for R2 instead of a link. Use a 270Ω resistor for a 12V battery and a 1.2kΩ resistor for the 24V version.

In particular, note that ZD4 and a 1.2kΩ resistor (for R2) must be used for the 24V version, unless the PIR can operate directly from a 28.8V supply.

IC1's socket can now go in, followed by IC2, REG1 & OPTO1 which can all be directly soldered to the PCB. Check that these parts are all correctly orientated before soldering their pins. Trimpots VR1-VR5 can then be installed. VR1 & VR2 are 20kΩ types and may be marked as 203. VR3 & VR4 are 10kΩ trimpots (103), while VR5 is a 500kΩ trimpot (504).

Once the trimpots are in, fit PC stakes to test points TP1-TP4 & TP-GND, then fit PC stakes to terminate the leads from inductor L1. That done, install switch S1 and the 3-way pin headers for JP1 & JP2.

Transistors Q2 & Q5 are next on the list. Make sure that Q2 is a BC337 and that Q5 is a 2N7000. Mosfet Q4 can then be installed; it's mounted horizontally on a small finned heatsink with its leads bent down through 90° so that they go through their respective holes in the PCB. Be sure to secure the assembly in place using an M3 x 6mm machine screw, washer and nut before soldering the leads.

There is no need to electrically isolate Q4's tab from the heatsink, so an insulation washer is not required.

Now for the fuse clips. These must go in with their retaining tabs on the outside, otherwise you will not be able to fit the fuse correctly later on. Once these are in, install the 0.01Ω 3W resistor.

The next step is to fit all the capacitors. Be sure to orientate the electrolytic types correctly. Note that the values and voltage ratings of the two large electrolytic capacitors at top left depend on whether the unit is built for 12V or 24V operation.

Follow with screw terminal blocks CON1-CON3. Note that CON1 uses large screw terminals in order to handle the heavy current requirements for the solar panel, battery and lamp connections. CON2 and CON3 are smaller units and are made up by dovetailing separate connectors together. In particular, CON2 uses a 3-way and 2-way connector, while CON3 uses two 2-way connectors.

Make sure that CON2 and CON3 are orientated with their openings towards the outside edge of the PCB.

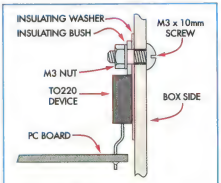
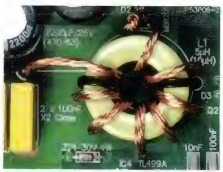


Fig.8: power devices D1, D2, Q1 & Q3 must be electrically isolated from the case using insulating washers and insulating bushes. After mounting each device, use your DMM (set to a high Ohms range) to check that the metal tab is indeed isolated from the case.

Power devices

Power devices D1, D2, Q1 and Q3 are all installed with their mount-

The external leads are fed into the case via cable glands. Additional cable glands will be required for the optional lamp, PIR and external switch connections.



Inductor L1 is made by twisting six 416mm-long strands of 0.5mm copper wire together and then winding on seven (or 10) turns – see text.

ing tab holes about 22mm above the PCB. In practice, this means mounting the devices on 10mm lead-lengths and that's best done with the aid of a 10mm-wide cardboard spacer slid between the device leads.

Be careful not to get these devices mixed up and note that the metal tabs go towards the outside edge of the board.

LED1 (centre, right) must be mounted so that it can later protrude through a hole in the side of the diecast case. It's just a matter of soldering it in at full lead length, then bending its leads over at right angles about 8mm above the PCB (eg, by bending it over a 8mm cardboard spacer). Be sure to orientate the LED correctly; its anode (A) lead is the longer of the two.

Winding inductor L1

Inductor L1 is wound using six strands of 0.5mm enamelled copper wire that are all twisted together. Begin by cutting 6 x 416mm lengths of wire, then strip about 15mm of enamel off each wire at one end. Lightly tin these wire ends, then twist the ends together and solder them.

Next, secure this soldered end in the chuck of a hand or battery-powered drill and twist all the wires together, so that each wire twists by 360° approximately every 20mm (see photos).

That done, wind seven turns (or 10 turns for the 24V version) through the toroid, spacing the turns evenly. Once they're on, position the inductor on the PCB and bend the soldered end so that it mates with one of the inductor's PC stakes. The other end can then be positioned to mate with its PC stake and cut to length.

Finally, strip back the enamel from the leads at this end, twist and solder them together and install the inductor on the PCB. A couple of cable ties fed through adjacent holes on either side of the inductor are then used to secure it in place.

Note that multiple strands of wire are used to minimise the impact of skin effect. If a single, larger wire had been used instead, its effective resistance at the switching frequency would be higher, leading to greater losses and more heating.

The approach taken here to reduce

Table 1: Resistor Colour Codes (12V Version)

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	3	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	68kΩ	blue grey orange brown	blue grey black red brown
❑	2	22kΩ	red red orange brown	red red black red brown
❑	2	10kΩ	brown black orange brown	brown black black red brown
❑	1	8.2kΩ	grey red red brown	grey red black brown brown
❑	2	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	2	2.2kΩ	red red red brown	red red black brown brown
❑	1	1.5kΩ	brown green red brown	brown green black brown brown
❑	2	1kΩ	brown black red brown	brown black black brown brown
❑	2	470Ω	yellow violet brown brown	yellow violet black black brown
❑	1	330Ω	orange orange brown brown	orange orange black black brown
❑	1 (opt.)	270Ω	red violet brown brown	red violet black black brown
❑	3	100Ω	brown black brown brown	brown black black black brown
❑	3	10Ω	brown black black brown	brown black black gold brown
❑	1	0.01Ω	not applicable	not applicable

Using The Solar Charger/Lighting Controller With 24V Batteries

As stated last month, the Solar MPPT Charger/Lighting Controller can also be used with 24V batteries and 24V solar panels. However, this requires some component changes to the circuit and these are indicated in brackets on Fig.7. In summary, the required changes are as follows:

(1) The 22kΩ resistor at pin 3 of IC2a is changed to 47kΩ, the 100Ω resistor feeding ZD2 is changed to 1kΩ and the 22kΩ resistor at the AN2 input of IC1 is changed to 51kΩ.

(2) The 2200µF 25V low-ESR capacitors are changed to 470µF 63V low-ESR types.

(3) The number of turns on inductor L1 is increased from seven to 10.

(4) If used, R2 should be increased to 1.2kΩ.

Several set-up changes are also required:

(1) The voltage at TP2 (set by VR2) must now be the battery voltage x 0.15625 (instead of 0.3125).

(2) The voltage set at TP3 for temperature compensation (step 8 in the setting up procedure) must be half that set for 12V operation. For example, for 38mV/°C compensation with a 24V battery, TP2 should read 1.9V (not 3.8V).

skin effect is similar to that of using Litz wire, except that the twisted wires are larger.

That completes the PCB assembly. The next step is to prepare the case.

Case drilling

The first step here is to drill two holes in one side of the case to accept two IP68 8mm cable glands, plus another hole in the opposite side for a 6.5mm cable gland. To do that, position the PCB inside the case and carefully mark out the positions for these cable glands. As shown in the photos, they are positioned opposite CON1 and CON3 and are centred vertically.

The PCB can then be removed from the case and the holes drilled and reamed to size. Deburr all edges with a small round file.

That done, the PCB can be temporarily repositioned in the case and the mounting holes for the four power devices (D1, D2, Q1 & Q3) and for LED1 marked out. Drill these holes to 3mm, then use an oversize drill to remove any metal swarf so that the area around each hole is perfectly smooth. This latter step is necessary to prevent punchthough of the insulating washers used with the power devices.

The PCB can now be secured inside the case using the supplied screws and the four TO-220 power devices attached to one side of the case, as shown in Fig.8. Note that it is necessary to isolate each device tab from the case using an insulating washer and insulating bush.

Once they have been installed, use a digital multimeter (set to read ohms) to confirm that the metal tabs are indeed isolated from the metal case. If a low resistance reading is found, check that the silicone washer for that particular TO-220 device has not been punctured by metal swarf.

If it has, then clear away the swarf and replace the insulating washer.

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
100nF	0.1µF	100n	104
10nF	0.01µF	10n	103
1nF	0.001µF	1n	102
470pF	NA	470p	471

Setting up

The step-by-step setting-up procedure is as follows:

Step 1: check that IC1 is out of its socket, then fit the fuse and apply 12V to the battery input terminals.

Step 2: connect a DMM between TP1 and TPGND and adjust VR1 for a reading of 5.0V.

Step 3: disconnect the 12V supply and wait for the 5V rail (measured at TP1) to drop to near 0V.

Step 4: plug IC1 into its socket, then reconnect the 12V supply.

Step 5: measure the voltage across the

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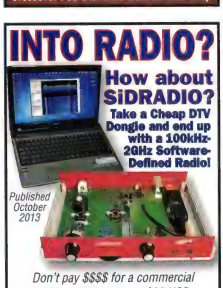

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Lighting & Inverter Options

As stated last month, jumpers JP1 & JP2 select the various lighting options. Here are a few suggestions:

(1) Night-time garden lighting: the light sensor allows the lights to switch on at dusk and they can remain lit for a preset period of up to eight hours, as set by the timer. Alternatively, you may wish to have the lights lit for the entire night and to switch off automatically at sunrise, provided there is sufficient battery capacity.

(2) Security or pathway lighting: the lights can be set to switch on after dusk but only when someone approaches the area. In this case, a PIR movement detector switches on the lights while the timer switches off the lights after the time-out period, typically 1-3 minutes or longer (8-hour maximum).

(3) Shed lighting: in this case, you may opt to switch the lights on and off using an external pushbutton switch. The lights can remain on until they are switched off again or they can switch automatically after a preset period, or at sunrise (as detected by an LDR).

Normally, the controller would be set so that the lights only come on when it is dark. However, you might want the lights on during day in a shed and this can be done using the third option listed in Table 1 last month; ie, JP1 in the night position, JP2 in the LDR position and the LDR left disconnected.

Using an inverter

As mentioned last month, you can directly switch up to 10A of 12V DC lighting via the LAMP terminals on CON1. Alternatively, instead of using 12V lamps, you can use an inverter to run 230VAC lamps.

This latter option requires the addition of an external relay (rated at 12VDC 150A) to switch the inverter on and off. Fig.10 shows the details.

As can be seen, the external relay's coil is connected across the LAMP terminals of CON1, while its NO (normally open) contacts switch the positive supply line from the battery through to the inverter. The negative supply terminal in the inverter is directly connected to the negative battery terminal.

A 150A relay is recommended to cope with the surge currents drawn by the inverter. If you are using a 24V battery, you will need to connect a 47Ω 10W resistor in series with the relay's 12V coil. Assuming that the relay has a 50Ω coil, this 47Ω resistor will effectively halve the voltage that's applied to the coil.

Note that the supply wiring to the relay and to the inverter must be rated to carry the inverter's current. A 12V 600W inverter, for example, will need supply wiring that's capable of carrying at least 50A.

Battery size

A minimum battery capacity of 80Ah is recommended. A larger battery can be used provided that you don't draw more out of the battery than the solar panels are able to top up. If you do use more power than the solar panels can provide, the battery will eventually be discharged.

LiFePO$_4$ charging

As mentioned, when using a LiFePO$_4$ battery terminals and multiply this by 0.3125.

Step 6: press switch S1 and wait for a few seconds, then connect a DMM between TP2 and TPGND and adjust VR2 so that the DMM reads the calculated figure. For example, if the battery terminal voltage is 12.0V, TP2 should read 3.75V.

Step 7: determine the recommended temperature compensation (in mV/°C) for your battery by looking up its specifications. Usually, there will be a graph which show the battery's fully charged voltage against temperature. You will need to determine the mV/°C figure from this graph.

Step 8: connect the DMM to TP3, hold down switch S1 and adjust VR3 until the meter shows the required temperature compensation value. This reading will be in the range of 0-5V, represent-

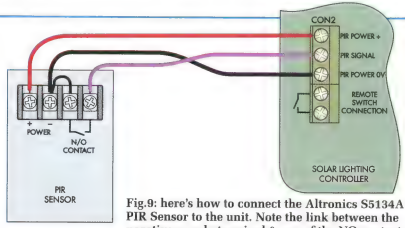


Fig.9: here's how to connect the Altronics S5134A PIR Sensor to the unit. Note the link between the negative supply terminal & one of the NO contacts.

Mounting & Connecting A PIR Sensor

An Altronics S5314A PIR sensor was used with our prototype unit but other similar PIR sensors will also be suitable.

The Altronics sensor can be configured for either a normally open (NO) or normally closed (NC) output. In this case, it's necessary to select the NO option using the supplied jumper.

Once that's done, the PIR sensor is connected to CON2 on the Solar Charge/Lighting Controller as shown above in Fig.9. Note the link between the PIR's negative power terminal and one of its NO contacts. The PIR's other NO contact connects to the PIR signal input on CON2.

In operation, the signal input terminal is normally pulled to +5V via R1 (100kΩ) on the controller's PCB. However, when movement is detected, the PIR's contacts close and the signal input is pulled down to 0V, thus triggering the controller and turning on the lights.

When mounting the PIR sensor, be sure to position it so that it covers the desired detection area. You can test its coverage by temporarily mounting it in position, connecting the 12V supply from CON2 and watching the detect LED in the PIR sensor light as you move around the detection area.

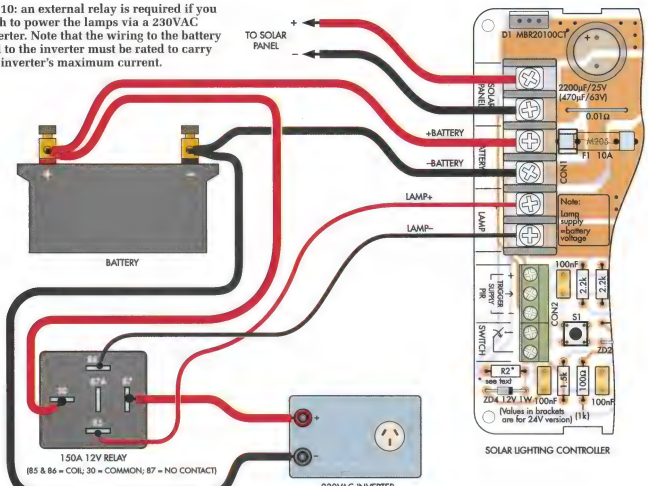


Fig.10: an external relay is required if you wish to power the lamps via a 230VAC inverter. Note that the wiring to the battery and to the inverter must be rated to carry the inverter's maximum current.

battery, the mV/°C setting using VR3 must be set to 0mV/°C. This allows the correct charging cycle for this battery chemistry.

In addition, a cell balancer should be connected to the balance connector on the battery. This is necessary to ensure that each cell that makes up the battery is charged to the same level as the others.

A suitable cell balancer is published elsewhere in this issue of Silicon Chip.

ing 0-50mV/°C; ie, 1V = 10mV/°C.

Note that this applies to lead-acid batteries only. If you have a $LiFePO_4$ battery, set VR3 fully anticlockwise for a 0V reading at TP3.

Thermistor connection

Thermistor TH1 can be directly connected to CON3 inside the case if you are not too concerned about temperature compensation. However, you would then be relying on the temperature within the case being similar to that of the battery.

The odds are that the case and battery temperatures will be different, though. So, instead of mounting it in the case, the best way to mount the thermistor is to tape it to the side of the battery and connect it to CON3 using single-core shielded cable (fed in via the cable gland). This lead should be soldered to the thermistor and the solder joints insulated with heatshrink tubing (polarity is unimportant).

Note that you must have the thermistor connected if the mV/°C adjustment, as measured, at TP3 is above 0V. If it's left out, LED1 will flash to give the disconnected thermistor indication and charging will not take place. Conversely, if VR3 is set to give 0V at

Cable Resistance Must Be Kept Low

When the Solar Charge Controller is used with a 120W panel, the charging current to the battery can be as high as 10A. Hence, the cable resistance between the Charge Controller and the battery should be made as low as possible, otherwise voltage losses will affect the changeover from the bulk charge to the absorption stage of charging. This will reduce the overall charging efficacy.

To minimise these voltage losses, mount the charger close to the battery and use heavy duty cables. For a total cable length of less than one metre (ie, total wire length for the positive and negative wires), cables with a cross-sectional area of 1.29mm^2 (eg, 41 x 0.2mm) can be used. This will result in a voltage loss of just 100mV at 10A.

For longer wire lengths, use heavier duty cable. For example, 8-gauge wire with 7 x 95/0.12mm wire and a cross sectional area of 7.5mm^2 can be used with a total length of up to 5.5m.

Table 3: Setting The Time-out Period

TP4 Voltage	Time-out Period (Approx.)	Adjustment Steps	Timeout Calculation (Approx.)
0-2.5V	2-250 seconds (approx. 4 minutes)	2 seconds	TP4 voltage x 100 seconds (2 seconds miniumum)
2.5-4.9V	4-480 minutes (up to 8 hours)	4 minutes	(TP4 voltage - 2.5V) x 200 minutes (4 minutes minimum)
Above 4.9V	No timeout		

TP3 (ie, 0mV/°C compensation), such as when using a $LiFePO_4$ battery, the thermistor can be left disconnected.

Connecting the LDR

The LDR will need to be connected to CON3 if you want the lighting to be controlled by the ambient light level. You then have to set jumpers JP1 & JP2 to determine whether the lights come on at night or during the day – see Table 1 last month.

As with the NTC thermistor, the LDR can be attached via a length of single-core shielded cable (or use figure-8 lead). The LDR should be mounted in a location where it receives ambient light only; not light from the lamps being switched by the Solar Charge/Lighting Controller.

An external switch can also be used for lamp on/off control. This should be a momentary-contact pushbutton switch. This is connected to CON2's switch terminals using figure-8 cable (ie, it connects in parallel with switch S1 on the PCB).

Another option is to connect a PIR sensor to CON2 and use that to control the lamp switching. An accompanying panel in this artricle describes how to do this.

Positioning The Solar Panel

The solar panel should be mounted on a roof or in some other position where it has an unobstructed view of the sky. In Australia, NZ and other southern hemisphere locations, it should be set facing north (or south for northern hemisphere locations).

The panel's inclination should be roughly 23° up from horizontal for NSW, SA, central/south WA and the North Island of NZ. Slightly higher angles are required for Victoria, Tasmania and NZ's South Island, while slightly lower angles will be needed for Qld, NT and northern WA.

If in doubt, check the inclination required on internet sites. In addition, take care to avoid any possibility of shadowing (eg, from a pole or tree) as the sun traverses the sky.

Setting the time-out period

Depending on your application, the timer will need to be set to an appropriate period. The time-out period can be adjusted from two seconds (2s) up to about eight hours using VR4.

Table 3 shows the time-out with respect to the voltage on TP4, as set by VR4. This adjustment must be made while S1 is pressed, with a multimeter connected between TP4 and TPGND.

For voltages up to 2.5V, the time-out period in seconds is simply the measured voltage multiplied by 100. For example, a 1V setting will provide a time-out of 100 seconds.

For TP4 voltages above 2.5V, it's a bit more complicated. The procedure is as follows: divide the required time-out period in minutes by 200, then add 2.5V to this figure and adjust VR4 until the voltage at TP4 matches the calculated value.

Note that the minimum time-out above 2.5V is four minutes. SC

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Hot-wire cutter with PICAXE heat controller

The concept behind hot-wire cutting is to use a variable power supply and heat a length of nichrome resistance wire to just below red heat. This enables the heated wire to melt most foam plastic or Styrofoam materials and allows you to cut straight lines or intricate shapes. Nichrome wire expands when heated and you must include a spring to keep the wire taut.

This hot wire cutter will cut foam materials up to 210mm thick and 250mm from an edge and requires a timber frame with a length of nichrome wire tensioned by a spring. The nichrome wire came from Jaycar (Cat. WW-4040) and the spring from Bunnings (Century type C215).

0.315mm Nichrome wire has a resistance of 13.77Ω per meter or 3.72Ω for the 270mm length shown in the diagram. While you could drive the hot-wire cutter from an an adjustable bench power supply (capable of 12V DC at over 3A), this circuit shows a better approach with a PICAXE-based heat controller and an ATX computer power supply.

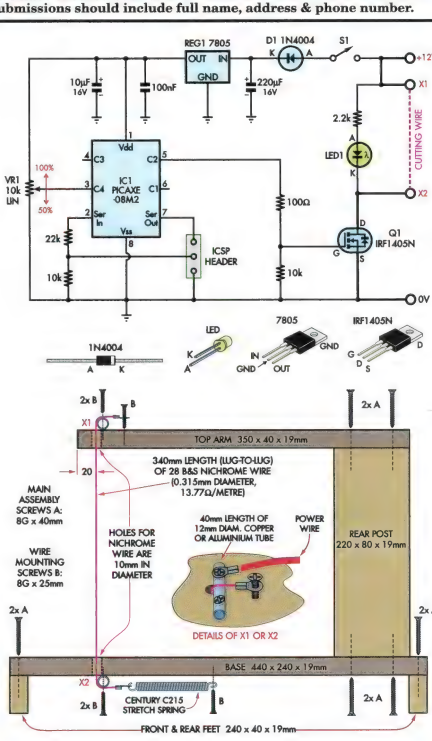
The PICAXE controller uses pulse width modulation at 5kHz with a variable mark space ratio and the average power delivered to the load, as set by VR1, can range from 50-100%, as needed. The 12V from the external power supply is fed directly to the hot-wire and Mosfet Q1, while 7805 regulator REG1 provides 5V DC to the PICAXE microcontroller (IC1).

If using an ATX supply, you will need a switch between the green wire and any black wire on the main 20-pin connector. Then connect any yellow and black wire as the 12V DC supply. Some supplies will need a 10Ω 10W load resistor across the 5VDC red and black wires.

The circuit shows an ICSP header to download the software into IC1 and uses pin 2 as the serial input and pin 7 as the serial output. You will require a special PICAXE serial or USB cable (www.picaxe.com); download the *hot-wire_08m2.bas* basic program from the website at www.siliconchip.com.au

Ian Robertson,
Engadine, NSW. ($70)

Editor's note: an alternative to this hot wire cutter was featured in the December 2010 issue (www.siliconchip.com.au/Issue/2010/December/A+HotWire+Cutter+With+Inbuilt+Heat+Controller) and a PCB is available from our Online Shop at www.siliconchip.com.au/Shop/8/825.



HOT WIRE CUTTER FRAME CONSTRUCTION DETAILS SCALE: 25% OF ACTUAL SIZE

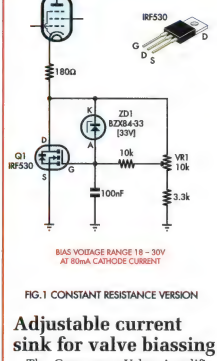


FIG.1 CONSTANT RESISTANCE VERSION

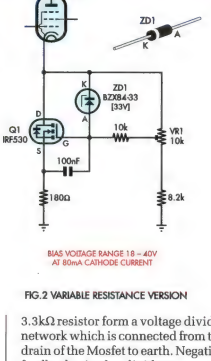


FIG.2 VARIABLE RESISTANCE VERSION

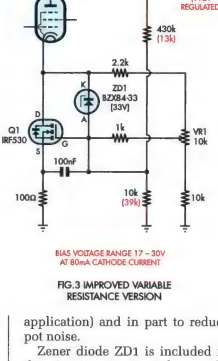


FIG.3 IMPROVED VARIABLE RESISTANCE VERSION

Adjustable current sink for valve biassing

The Currawong Valve Amplifier project has stimulated significant interest in valve amplifier design and in particular, the concept of a variable cathode resistance for valve output stages. These designs are based on a Mosfet as an adjustable shunt regulator which is connected between the cathode of a valve (V1, V2, V3) and earth.

In Fig.1, the Mosfet is configured essentially as a constant voltage shunt regulator. The circuit relies on the fact that a typical power Mosfet has a non-zero gate threshold voltage which can be used as a voltage reference in an appropriately designed negative feedback network. This makes such Mosfets suitable for use in simple shunt regulator circuits.

However, bear in mind two things: First, the gate turn-on voltage varies widely between Mosfets of different types and to a lesser extent, between Mosfets of the same type. Second, the turn-on voltage of a Mosfet is somewhat temperature dependent. As a result, it is important to take these factors into account before using this kind of circuit in critical applications.

The circuit in Fig.1 works as follows: trimpot VR1 together with the 3.3kΩ resistor form a voltage divider network which is connected from the drain of the Mosfet to earth. Negative feedback via the divider networks causes the Mosfet to maintain a relatively constant voltage across its drain-source terminals over a wide range of operating currents.

The gate threshold voltage of the specified Mosfet is about 4V and hence, by negative feedback action, the drain-source voltage is approximately the gate turn-on voltage (ie, 4V) multiplied by the resistance ratio R/Rx where R is the total series resistance and Rx is the resistance from the wiper of the trimpot to ground.

Because the Mosfet acts as a constant voltage shunt regulator, the dynamic resistance of the circuit is determined essentially by the 180Ω series resistor. In principle, this resistor can be omitted if one wants a constant voltage at the cathode (a constant valve cathode bias voltage). However, in practice, a small amount of dynamic series resistance between cathode and earth may be useful to reduce variations in the valve plate current due to changes in operating temperature, valve aging etc.

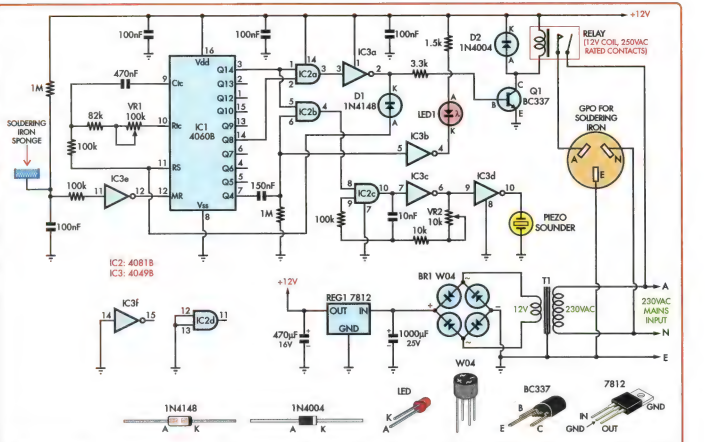
The 10kΩ resistor and the 100nF capacitor form a low-pass filter, in part to reduce the high-frequency response of the circuit (which in general is desirable in this kind of application) and in part to reduce pot noise.

Zener diode ZD1 is included in the circuit to protect the Mosfet from any unexpected voltage spikes, arising from current surges within the valve such as might result from internal flash-over. The idea is that if a current surge should occur, any resulting current flowing through the zener would cause the gate voltage to rise. The rise in gate voltage, in turn, would cause the Mosfet to conduct more heavily, thereby shunting any excessive energy to earth before damage to the Mosfet occurs.

Alternatively, a high power (eg, 3W) zener diode could be connected directly across the drain-source terminals of the Mosfet to protect it.

Figs.2 & 3 differ from Fig.1 primarily in that the cathode series resistor is incorporated within the feedback circuit (between source and earth) and this gives the shunt regulator a variable dynamic resistance, depending on the setting of the pot.

The circuit in Fig.3 can be regarded as an "improved variable resistance version" for two reasons: First, it shows improved linearity in the voltage-current curves in the low current region and second, it has a wider range (particularly at low plate currents). These improvements are achieved by including an external



Soldering iron timer

Timers are available to turn power off after a preset time but this design is specifically intended for soldering irons and has two extra features. First, the timer is automatically reset every time the soldering iron tip is wiped across the wet sponge and second, it beeps near the end of the set period to remind the user it is about to switch off.

The timer is based on a 4060 CMOS timer, IC1, which has an internal oscillator and 14-stage binary counter. Not all stages have connection to external pins and the clock speed is set by the components connected to pins 9, 10 & 11.

With the clock set to 7Hz, the time-out is about 20 minutes, with beeper alert during the last 18 seconds. A higher clock speed will result in a shorter time-out time and vice versa.

The tip cleaning sponge, which must be wet and isolated from earth, is connected to the 12V rail via a 1MΩ resistor. When the tip (which must be properly earthed) touches it, the 4049 inverter input is pulled low, providing a positive reset pulse to pin 12 of the 4060.

The 100kΩ resistor and 0.1µF capacitor provide some noise immunity and ESD protection.

During operation, when output Q4 (pin 7) of IC1 goes high, a short pulse (100ms) is generated each 2.3 seconds, causing LED1 to flash. After about 19 minutes, when output Q14 (pin 3) goes high, the beeper section is activated and the piezo element beeps briefly each time the LED flashes.

The timing ends and the relay turns off when Q14 is high and Q8 becomes high.

A 12V relay with 250VAC-rated contacts (SPST) typically requires 30mA and the 12V DC power supply should be able to deliver 60mA.

Caution: for safety reasons, soldering irons should not be left on unattended

Charles Tivendale,
Edithvale, Vic. ($60)

bias voltage that compensates for the non-zero gate turn-on voltage of the Mosfet.

Without the external bias voltage, the minimum voltage that the shunt regulator circuit can maintain is equal to the gate turn-on voltage, which in this case is about 4V. You can reduce the minimum shunt voltage by using a Mosfet with a lower turn-on gate voltage but you cannot reduce the shunt voltage to zero without modifying the circuit.

By incorporating an external bias voltage as shown, you can compensate for the gate turn-on voltage so that in principle, the shunt voltage could be arbitrarily as close to zero as possible.

However, the optimal compensating bias voltage in Fig.3 varies with the setting of the trimpot. The challenge, when designing a circuit such as this, is to configure the circuit so as to minimise that variation and thereby to obtain the best possible compromise over the full range of the pot. The component values are rather critical if you want to obtain optimal performance over a desired operating range.

Herman Nacinovich,
Gulgong, NSW. ($80)

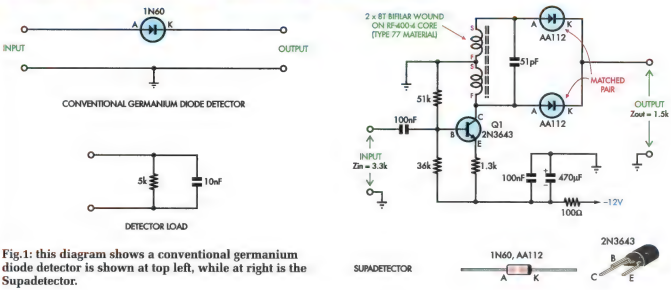


Fig.1: this diagram shows a conventional germanium diode detector is shown at top left, while at right is the Supadetector.

Improved AM detector has low distortion

A germanium detector diode, like any diode with forward voltage drop, gives a very distorted response when the signal amplitude is below a few hundred millivolts and it has square law properties in that zone.

To make the detector work well at low signal levels, it can be forward biased. But the amount of forward bias needs to be temperature-compensated and exactly right for the germanium diode junction and not too dependent on battery voltage. You can also do this in crystal sets etc to make the diode work better on weak signals.

This "Supadetector" was designed to replace the germanium detector in some communications radios. It acts as though it has little forward voltage drop, like an op amp precision detector but it uses a transistor and two diodes for full-wave rectification.

Although it looks just like a single RF stage, it has a high load impedance provided by a bifilar-wound inductor which drives two diodes. This means there is a severe mismatch between the inductor and the detector load but even at low

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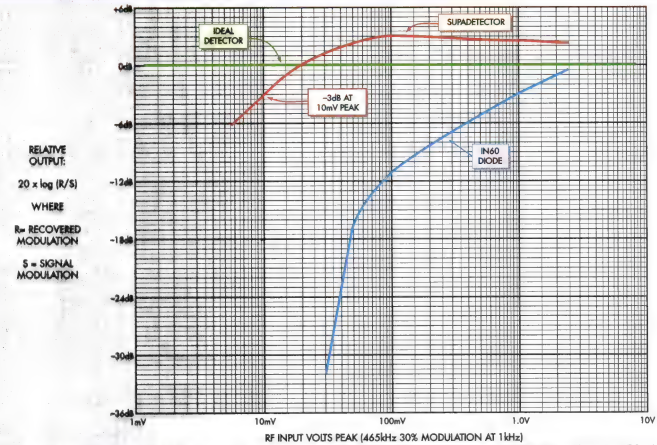


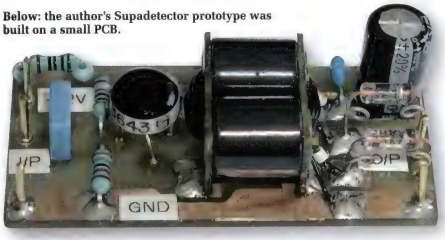
Fig.2 above: this graph shows the output response curves for an ideal detector (green), a 1N60 diode detector (blue) and the Supdetector circuit shown in Fig.1.

signal levels, the inductor voltage rises high enough to maintain a good diode current.

The accompanying graph (Fig.2) shows the straight line output of an ideal detector (green) while a 1N60 diode is shown in blue. The Supadetector (red) is a great improvement and still shows quite good performance for signals below 10mV peak (7mV RMS).

This version of the circuit was for use in a positive ground radio but it can be made a number of ways for positive or negative ground circuits and transistors of either polarity. It pays to have coiled loops on the germanium diode wires to prevent physical trauma to the glass and thermal trauma to the junction when soldering.

Below: the author's Supadetector prototype was built on a small PCB.



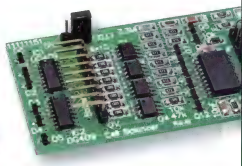
The original idea to drive a diode with a current source and not a voltage source, to overcome low level signal non-linearity in a detector is noted in Horowitz & Hill's textbook *The Art of Electronics*.

Hugo Holden,
Minyama, Qld. ($70)

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We need it and will pay good money to feature it in the Circuit Notebook pages. We can pay you by electronic funds transfer, cheque (what are they?) or direct to your PayPal account. Or you can use the funds to purchase anything from the SILICON CHIP on-line shop, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au or post it to SILICON CHIP, PO Box 139, Collaroy Beach, NSW 2097.

Battery Pack Cell Balancer



Many multi-purpose chargers can handle lithium-ion, lithium-polymer or $LiFePO_4$ batteries. But they may not balance the charge between individual cells and this can lead to incomplete charging and premature failure. This small device solves this by providing the balancing function separately. It can also be used with Nicad and NiMH packs for a longer life-span and is suitable for use with the MPPT Solar Lighting Charger/Controller published elsewhere in this issue.

By Nicholas Vinen

TRADITIONAL BATTERY chargers treat a battery as a device having two terminals, delivering current until the battery voltage reaches a certain level. The termination voltage is the fully-charged cell voltage multiplied by the number of cells and the assumption is that the when the battery reaches this voltage, each cell is fully charged. However, this relies on the cells being identical.

Similarly, the battery is determined to be flat when the overall voltage reaches a level indicating that each cell is fully discharged. But if one cell starts out with a lesser charge or discharges faster for some reason, it could be over-discharged before this threshold is reached. This could damage the cell, leading to lower capacity and a shorter battery-pack life.

It's quite typical for a battery-pack to fail because the internal resistance of just one cell has gone high. The charge and discharge current must flow through all cells, so once one cell can no longer pass enough current, the whole battery is useless. Similarly, if one cell's voltage is especially low (or perhaps even negative), the fully charged battery voltage may be insufficient even though the rest of the cells are healthy.

So for the longest battery life you need to ensure that all cells are charged and discharged equally. Even with a brand new battery, cell capacity may vary slightly (by one ot two percent, say) but over time, this can worsen. This effect is greater with lithium-based cells than other types, which is why it's important to ensure they are properly balanced during charging.

Consider a 4-cell LiPo battery with one cell that has 2% lower capacity than the others. All cells start out fully discharged at 3V, ie, the battery is at 12V. It is then charged to 16.8V, which we would expect to yield 4.2V per cell. However, since the lower capacity cell will charge faster, it may have reached 4.3V while the other cells are all at 4.166V. 4.3V + 4.166V x 3 = 16.8V, so the charger can't tell the difference.

This cell has now been over-charged and this could lower its capacity further, to say 3% below the rest. Despite its lower capacity, it has a higher charge state than the other cells, so after discharge the voltages may be equal again. But eventually its capacity could drop so much that it also starts discharging further than the other cells each cycle, accelerating the damage.

The simple solution is to monitor

Features & Specifications

- Balances Li-ion, LiPo or $LiFePO_4$ batteries with 2-8 cells
- Can also balance NiMH or Nicad packs with 4-8 cells
- Fully charged battery voltage of up to 33.6V (8 x 4.2V)
- Suitable for use with chargers up to 10A
- Will work with chargers >10A but not as effectively
- Cell balancing shunt current: ~200mA
- Very low quiescent current: <25µA
- Compact PCB can be mounted next to battery pack
- Works with virtually any non-balancing charger
- Plugs straight into typical battery balance connectors
- No external power required
- Automatically detects number of cells
- Detection of charging by cell voltage or via external signal
- Adjustable cell voltage balance start threshold via resistor
- LEDs indicate balance status

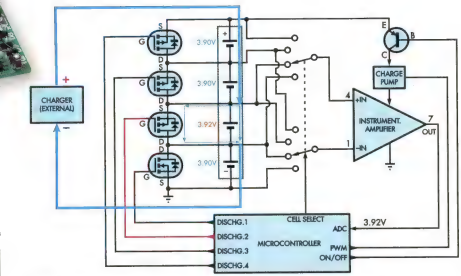


Fig.1: a simplified circuit showing the general principle of cell balancer operation. We're showing four cells but our balancer will work with up to eight. Mosfets are connected across each cell, to divert some of the charge current if that cell's voltage rises higher than the others. Analog switching, driven by a microcontroller, allows each cell to be connected across the inputs of an instrumentation amplifier, so the micro can measure that cell's voltage. A charge pump is used to provide sufficient voltage for the instrumentation amplifier to operate, while a transistor allows its supply to be switched off when it isn't being used.

the voltage of each cell during charging and shunt current around those cells which have a higher voltage than the others. This reduces the charge delivered to lower capacity cells, so they all reach the correct charge termination voltage simultaneously. This not only prevents weak cells from being over-charged but also stops strong cells from being under-charged.

Arguably, it's a good idea to monitor and balance cell voltages during discharge too, however if balancing occurs during charging, this should hopefully keep the cells healthy and they will discharge at a more or less equal rate. Serious imbalances normally take multiple charge/discharge cycles to build up, so regular cell balancing during charging is thought to be sufficient.

However, should you wish to balance a battery pack while it's being discharged, our unit can do that too. It can be constantly active, drawing very little current until an imbalance is detected, at which point it "wakes up" and attempts to rectify it.

Our cell balancer

The concept of a cell balancer is quite simple. It periodically checks the voltage of all cells. If one cell has a significantly higher voltage than the others, some of the charge current is shunted around it or if the battery is not currently being charged, it is discharged slightly. This reduces its voltage back in line with the others. This process is continuous so that as soon as any cell's voltage starts rising above the others, it is brought back in line.

Block diagram

The basic principle is shown in the simplified circuit of Fig.1, drawn with a 4-cell battery. Blue arrows show the flow of current from the charger through the battery. The second cell has a higher voltage than the others, so the microcontroller enables the corresponding Mosfet to divert some of the charge current around it.

There are some complications to this approach. Cell voltages will need to be measured accurately so that small imbalances can be detected before they become significant. Ideally, inter-cell error should be around 10mV or less.

This will prevent unnecessary shunting/discharging of the cells due to measurement error. In the worst case, if there is a bias in the way the balancer measures cell voltages, it could actually imbalance an already balanced pack!

Also, if the balancer is to be left connected to the battery pack (which, in fixed installations, it would be), it needs to have negligible drain when the battery is not being charged or balanced. Ideally, it should be able to detect when charging is occurring and switch off for the rest of the time.

It also needs to be able to shunt a sufficiently large percentage of the charge current to be able to "keep up" with the rate at which cell imbalance can occur, without this resulting in excessive dissipation which could cause undesired heating of the balancer or the battery.

It should also ideally suit a wide range of battery types, from two cells or more and including all the different chemistries that may require balancing.

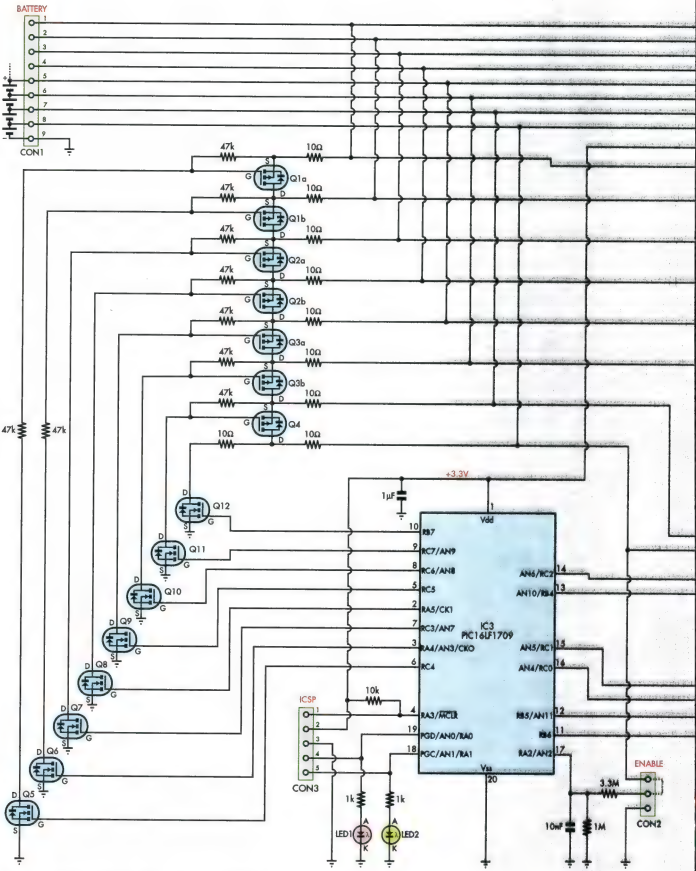
In order to accurately assess the difference in cell voltages, we've avoided using a voltage divider. If we had simply connected each cell to a micro's ADC inputs with its own divider, it would be difficult to assure cell-to-cell accuracy. And if we used dividers after some sort of analog switching arrangement, they would have to be very accurate to keep the common mode rejection ratio (CMRR) high enough.

Independent cell measurement

Instead, we are using analog switches to connect one cell at a time to an instrumentation amplifier. This is effectively a differential op amp with a very high input impedance and a very high CMRR. These both contribute to providing very good differential voltage sensing accuracy. Its output is the voltage of the selected cell and this is then fed to the ADC input of a microcontroller.

The micro we have chosen is a PIC16LF1709, running at 3.3V. This has a 10-bit ADC which is sufficient to sense cell voltages with a resolution of less than 5mV or even better with averaging. It's also capable of an ultra-low-power sleep mode, to minimise current drain when balancing is not occurring. To this end, it has been teamed up with an ultra-low quiescent current regulator and it can switch power to the instrumentation amplifier off when it isn't being used.

Current is shunted around a cell during charging, or the cell is partially discharged, by switching on a Mosfet connected across the cell with a pair of current-limiting resistors. These



BATTERY CELL BALANCER

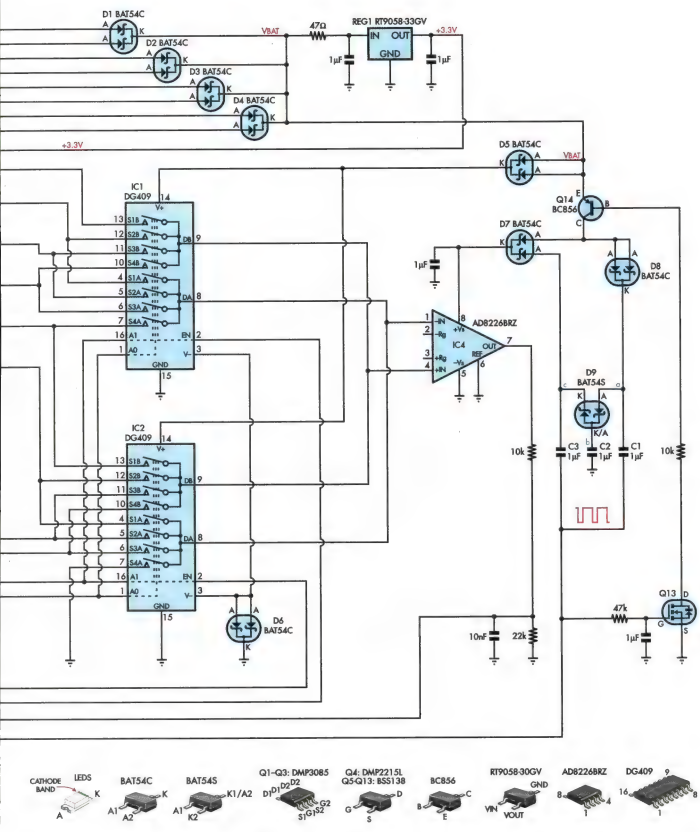


Fig.2: the complete Cell Balancer circuit. Cell voltages at CON1 are connected to instrumentation amplifier IC4 by high-voltage analog switches IC1 and IC2, then to microcontroller IC3's AN11 analog input. IC3 can then switch on one of Mosfets Q5-Q11 which in turn activate Mosfets Q1a-Q3b or Q4 to shunt current around or discharge the cell with the highest voltage. The bottom-most cell is shunted directly by Mosfet Q12. IC3's pin 11 output drives a charge pump to boost IC4's supply so it can operate over the entire battery voltage range.

Parts List

1 double-sided PCB, code 11111151, 69 x 35.5mm
1 3-way to 9-way pin header, 2.54mm pitch, straight or right angle to suit battery pack (CON1)
1 3-way pin header, 2.54mm pitch, with optional jumper shunt (CON2)
1 5-way pin header, 2.54mm pitch, straight or right angle (CON3, optional, for ICSP)
1 100mm length of heatshrink tubing, 50mm diameter (optional)

Semiconductors

2 DG409DY quad high-voltage CMOS switches, SOIC-16 (IC1,IC2)
1 PIC16LF1709-I/SO 8-bit microcontroller programmed with 1111115A.hex, SOIC-20 (IC3)
1 AD8226BRZ single supply instrumentation amplifier, SOIC-8 (IC4)
1 RT9058-33GV 3.3V (36V in) 100mA low-dropout, low-I_Q regulator, SOT-23 (REG1)
1 high-brightness red LED, SMD 3216/1206 (LED1)
1 high-brightness green LED, SMD 3216/1206 (LED2)
3 DMP3085 dual 30V P-channel Mosfets, SOIC-8 (Q1-Q3)
1 DMP2215 20V P-channel Mosfet, SOT-23 (Q4)
9 BSS138 logic level N-channel Mosfets, SOT-23 (Q5-Q13)
1 BC856 PNP transistor, SOT-23 (Q14)
8 BAT54CFILM dual 40V Schottky diodes, SOT-23 (D1-D8)
1 BAT54SFILM dual 40V Schottky diode, SOT-23 (D9)

Capacitors (SMD 3216/1206, X5R/X7R)

8 1µF 50V
2 10nF 50V

Resistors (SMD 3216/1206, 1%, ¼W)

1 3.3MΩ*	3 10kΩ
1 1MΩ	2 1kΩ
10 47kΩ	1 47Ω
1 22kΩ	9 10Ω 0.5W**

* change to set balance start voltage threshold
** 4.7Ω 0.5W preferred for use with NiMH/Nicad

Mosfets are controlled by individual output pins on the microcontroller.

Circuit description

The full circuit of the cell balancer is shown in Fig.2. The battery balance connector is usually a 2.54mm-pitch JST type which plugs into CON1 with the negative-most terminal to pin 9, as shown. Between two and eight cells are connected and with fewer than eight cells, some pins will not connected.

The terminals of CON1 are wired directly to the inputs of two dual 4-to-1 multiplexer ICs, IC1 & IC2. These DG409s will tolerate up to 44V and have a maximum on-resistance of 100Ω. They are wired so that, depending on the state of their control input pins (A0, A1 and EN), one cell at a time can be connected to the inverting and non-inverting inputs of instrumentation amplifier IC4 (pins 1 & 4).

For example, if A0 and A1 are low (0V) and the enable pin of IC1 is high, pin 1 of CON1 is connected to pin 4 of IC4 while pin 2 of CON1 is connected to pin 1 of IC4. Therefore, the voltage across the top-most cell of the battery (assuming it has eight) appears across IC4's inputs. IC4 is configured for unity gain, with no resistor between pins 2 & 3. Thus, the difference between the voltage at either end of the selected cell appears at output pin 7.

This is fed to analog input AN11 (pin 12) of the PIC16LF1709 microcontroller via a 10kΩ/22kΩ resistive divider, with a 10nF capacitor connected across the bottom leg to act as a noise filter. The divider ensures that even with a fully-charged lithium-ion or lithium polymer battery, with a cell voltage of up to say 4.3V, no more than 2.96V will be fed to IC3 and this is well below its 3.3V supply, which also acts as the ADC reference voltage.

So basically, the micro can measure the voltage across each cell by controlling the state of its output pins 13/RB4 (to A0), 14/RC2 (to A1), 15/RC1 (to IC2 EN) and 16/RC0 (to IC1 EN). Because it uses the same circuitry in each case, errors should be consistent, making for accurate cell voltage comparisons.

IC4 has a CMRR of at least 90dB with unity gain, so the error due to absolute cell voltage variation is tiny – with 30V between the bottom and top cell voltages, the resulting error will be less than 1mV. Besides noise, the other source of error is variation in the on-resistance between the analog switches in IC1 and IC2. However, since IC4 has an extremely high input impedance of around 400MΩ, this error will also be negligible; less than 10µV.

Cell balancing

During charging, microcontroller IC3 scans the cells about once per second, to determine if there is a significant difference in their voltages. If there is, it switches on one of Q1a-Q3b, Q4 or Q12 to shunt some current around it, reducing that cell's charge rate.

One of these Mosfets is connected across each cell, with a 10Ω series resistor at either end (the bottom cell is slightly different). Many of these resistors are shared, to cut down on the component count, meaning normally only one Mosfet will switch on at a time, to keep dissipation within component limits.

The bottom-most cell is discharged by N-channel Mosfet Q12. Its gate is driven directly from output pin 10 (RB7) of micro IC3 and when that line goes high, it sinks current from the positive terminal of this cell through a pair of series-connected 10Ω resistors to ground. Assuming this is a fully-charged Li-Po cell at around 4.2V, the shunt current is 4.2V ÷ 20Ω = 210mA.

If the battery is being charged at, say 5A, this means that 4.2% of the charge current will be shunted around this cell, so it will charge more slowly than the others and eventually the voltages will re-balance. If charging is not occurring then this cell will simply discharge at a rate of 210mA, until its voltage has been reduced to be in line with the other cells.

The other seven cells (or however many are present) are discharged by one of P-channel Mosfets Q1-Q4. Six of these are part of DMP3085 dual Mosfets while the seventh is a single DMP2215 Mosfet. Each is normally held off by a 47kΩ resistor between its gate and source terminal, and switched on when the gate is pulled to ground by one of Q5-Q11, which are small-signal N-channel Mosfets.

Like Q12, these are driven directly from the outputs of micro IC3, from

pins 2-9. These are logic-level Mosfets and require less than 2V at the gate to sink more than 100mA. Q5-Q11, in combination with the gate pull-up resistors, effectively form level shifters to provide the different voltage levels to drive the gates of Q1-Q4.

The DMP3085 Mosfets used have a maximum gate-source voltage of 30V, so Q2 and Q3 require no gate voltage limiting. Q4 does not require gate voltage limiting either as it's connected across the second-from-bottom cell and so its source will never be more than 9V above ground. However, for Q1a and Q1b, two extra 47kΩ resistors are connected between the drains of Q5/Q6 and their gates to reduce the gate drive voltage to a maximum of -20V.

The discharge Mosfets do not need to be switched quickly, so the relatively high-value 47kΩ resistors do not interfere with their function.

Power supply

REG1 is fed the full battery voltage via one of dual Schottky diodes D1-D4. A 47Ω filter/dropper resistor reduces dissipation in REG1, an SMD 3.3V low-dropout linear regulator, while also filtering out any hash from the charger or spikes from discharge pulses.

The 3.3V rail supplies microcontroller IC3 and is also used as a reference voltage for its ADC, as stated earlier.

The V_{BAT} rail from the cathodes of D1-D4 also powers multiplexers IC1 and IC2 via series Schottky diodes D5 and D6. These diodes provide protection for IC1 and IC2 against over-voltage at their inputs, since their internal clamp diodes will automatically boost the supply if this happens (and D5/D6 would become reverse-biased). Normally this is not an issue but when a battery is initially plugged in, not all of its pins may make contact at the same time, so we're protecting these ICs as per the suggested arrangement in the data sheet.

The power supply for IC4 is somewhat more complex. To avoid draining the battery when it isn't being charged or balanced, micro IC3 switches off IC4 using PNP transistor Q14. To switch Q14 on, IC3 drives its RB6 output high (pin 11), which charges N-channel Mosfet Q13's gate via an RC filter. Q13 then sinks current from Q14's base via a 10kΩ current-limiting resistor, turning it on and allowing current to flow to IC4's supply pin via D7.

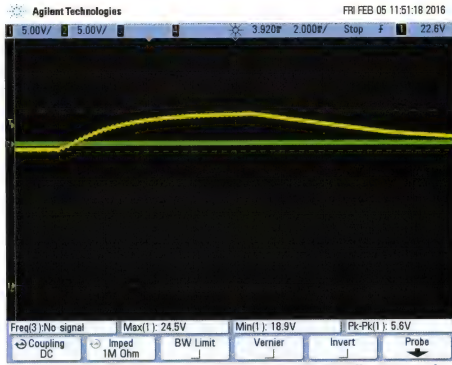


Fig.3: operation of the charge pump which supplies IC4. Initially, IC4's supply (yellow) is below the battery voltage (green) due to the two Schottky diodes and one PNP transistor its supply current must pass through. Once the charge pump begins operation, it quickly climbs above the battery voltage, eventually settling about 4V higher after 8ms or so. The micro then quickly takes the measurement using its ADC before the supply voltage drops.

But that isn't the end of the story because while IC4 can handle input voltages down to its negative rail (ie, GND), the inputs must remain below its positive rail for correct operation. The voltage between the positive-most input and the positive supply rail must be at least 1V plus half the output voltage to remain in the common-mode operating range, which in our case means we need a "headroom" of around 3.1V (1V + 4.2V ÷ 2).

The forward voltage of D1-D4 & D7 means that normally IC4's supply will be around 0.6V below the positive-most battery terminal, so we need to boost its supply by 3.1V + 0.6V = at least 3.7V to correctly sense the top cell voltage.

So, before measuring the voltage of the top-most cell, after RB6 is brought high and the 1μF capacitor at Q13's gate is fully charged, IC3 pulses its RB6 output around 50 times before taking the first measurement, with a frequency of around 5kHz. This drives a charge pump which increases IC4's supply voltage to about 4V above the battery voltage, allowing it to properly measure the voltage of the top cell(s).

Fig.3 shows how the supply voltage to IC4 rises during this period, from a little below the 20V battery voltage in this example to around 24V.

It works as follows: when RB6 goes low, 1μF capacitor C1 charges from the battery supply via Q14 and D8, to around 0.75V less than the battery (point "a", Fig.2). When RB6 goes high again, point "a" increases by about 3.3V, to around 2.5V above the battery voltage. C2 is then charged to slightly less than this (at point "b"), via one half of dual series Schottky diode D9.

When RB6 next goes low, C3 charges to around 2V above the battery voltage via the second half of D9 (point "c"). When RB6 goes high again, point "c" is boosted to around 4V above the battery voltage and current flows through the lower half of dual Schottky diode D7, forming IC4's supply. This drops a little during RB6's off-time but remains sufficiently high to complete several ADC conversions.

By starting with Q13's gate at 3.3V and keeping the duty cycle relatively high, Q13 is prevented from switching off before the charge pump has done its work, despite the fact that RB6 is being modulated.

Balance current

The 10Ω resistors have been chosen

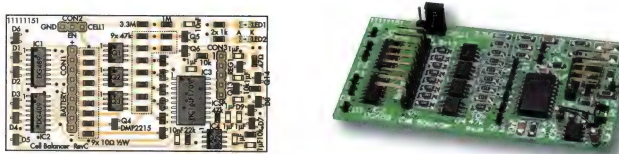


Fig.4: all SMD components are mounted on the top of the double-sided PCB. The pin headers can be straight or right-angle types and can be fitted on either side. Take care with the orientation of IC1-IC4, Q1-Q3, LED1 & LED2. The other components are either non-polarised or their orientation is fairly obvious. Note: photo shows prototype PCB assembly.

to limit current to a safe level with lithium-based rechargeable cells. For NiMH/Nicad, since the cell voltage is substantially lower (less than half), ideally 4.7Ω 0.5W resistors should be substituted. The unit will still operate with 10Ω resistors but the shunt current will be below 100mA and this may be insufficient to keep the cells balanced, depending on the charge current.

Note though that 4.7Ω is too low for use with Li-ion, LiPo and $LiFePO_4$ batteries as they would dissipate nearly 1W each $((4.3V \div 2)^2 \div 4.7\Omega)$.

Software operation

The first thing that the software does, after setting up the input and output pins, is to determine the number of cells in the battery by measuring the voltage of each one and checking that it is above a minimum threshold. It expects to find a contiguous set of at least two cells starting from the bottom; otherwise, it flashes red LED1, waits a little while, then checks again. Once a valid battery has been detected, normal operation begins.

When checking for the presence of a cell, the corresponding shunt/discharge Mosfet is switched on briefly to remove any stray charge that may be present, which could give a false reading.

The main loop checks the voltage on pin 17 and goes into a sleep mode if it is below the 0.95V threshold (corresponding to a 4.085V trigger threshold with the values shown in Figs.1 & 3). After spending some time in low power sleep mode, the watchdog timer wakes the chip up and the pin 17 voltage is checked again.

Assuming pin 17 is at least 0.95V, the software switches on power to IC4, waits for its bypass capacitor to charge, then initiates the charge pump to bring its supply voltage up. Once that's complete it quickly scans the cells, from the highest to the lowest, measuring the voltages and storing them. It then makes a decision about whether to shunt/discharge any cells. If they're all basically equal, it ceases balancing and goes back to the main loop.

If balancing starts, the cell with the highest voltage is shunted/discharged. If there is a tie then they are handled in a round-robin fashion to balance the shunt current evenly. Each time, after a few seconds of shunting/discharging, the cell voltages are re-checked and a new decision is made.

Balance initiation

You can connect an external signal to pin 2 of CON2 to initiate balancing; for example, you could connect an output from your battery charger that goes high (to at least 4.5V) during charging. For a lower threshold, reduce the value of the 3.3MΩ resistor. For example, to suit a 3.3V signal, use a 1MΩ resistor, setting the threshold to 1.9V.

Alternatively, you can short out pins 1 & 2 of CON2, eg, with a jumper shunt. Balancing then starts whenever the bottom-most cell of the pack exceeds 4.1V. This voltage was chosen so that when a Li-ion or Li-Po battery is approaching full charge, balancing will begin but will cease once the battery has been discharged below approximately 90% of full charge. This prevents unnecessary battery drain if the cells become imbalanced during discharge.

There's no inherent reason why cells can not be balanced during discharge; in fact, arguably this is a good idea. However, it will increase battery current drain slightly and may reduce shelf-life after charging. It may also trigger low-battery cut-out on the powered device earlier. However, this could be a good thing as it will prevent any single cell from being over-discharged.

The balance initiation threshold can also be changed by selecting a different value for the 3.3MΩ resistor. Simply take the desired cut-off voltage, divide by 0.95, subtract one and pick the nearest resistor value in megohms. This will be necessary for different battery chemistries (eg, NiMH).

Construction

All components are fitted to one side of the PCB, with the possible exception of the headers, depending on your requirements. Use the PCB overlay diagram, Fig.4, as a guide for assembly.

Start by fitting the ICs. The simplest method is to apply a little solder to one of the pads, then heat that solder while sliding the IC into place. Once you've done that, check carefully that pin 1 is orientated correctly, which is usually indicated by a divot or dot in the corner.

Failing that, look for a bevelled edge on the IC package. Then check that all the pins are correctly centred over their pads. If not, reheat the initial solder joint and nudge the IC into place. You can then solder the remaining pins and, finally, refresh the initial solder joint.

Follow with Mosfets Q1-Q3 which are in similar packages to IC4. Next, install all the components in SOT-23 packages which includes all the diodes, the remaining Mosfets and bipolar transistor Q14, as well as REG1. A similar method can be used, where one pin is tacked down before the other two are soldered and the initial joint refreshed. Be careful not to get any of these parts mixed up as they all look very similar.

Follow with the resistors and capacitors using a similar technique. The resistors will have an abbreviated code printed on the top showing the

value, eg, 223 for 22kΩ (22×10^3). The capacitors will be unmarked although you will probably be able to pick them apart as the 1µF types should be physically larger. If you're planning on using 4.7Ω resistors rather than 10Ω, keep that in mind.

That just leaves two SMDs, both LEDs. You will need to determine which end is the cathode. This is often marked on the package with a green dot, however we've seen LEDs which mark the anode with a green dot too, so it's safest to check. Generally, this can be done with a DMM set on diode test mode. Probe each end of the LED with the leads. If it lights up, the red lead is connected to the anode and the black to the cathode. If not, try flipping the LED around.

Once you've worked out which end is the cathode (and also revealed the colour), solder it in place. Note that LED1 is red and LED2 is green and that the cathode (indicated with a K) goes towards the righthand edge of the PCB.

Battery connector CON1 can be soldered to either side of the PCB and you can use a straight or right-angle header. We used a right-angle header on the top of the board to minimise the overall thickness of the unit. You may wish to use a header with fewer than nine pins, to suit your battery connector, as this will make it easier to plug in. However, you could just solder in a 9-pin header to suit any battery pack with 2-8 cells.

CON3 can be omitted if your microcontroller is already programmed. We used a right-angle programming header, again to minimise thickness.

For CON2, we used a straight header as we simply fitted a jumper shunt so that balancing would begin automatically once the battery reached a sufficient cell voltage. However, you could simply fit a wire link between "EN" and "CELL1" if desired. Alternatively, connect a pair of wires between GND and EN, with or without the pin header.

Note that, while it would be possible to leave out some components if you do not need to handle batteries with more than six cells, we'll leave it to individual constructors to figure out which ones can be omitted.

Usage

If IC3 has not already been programmed, download the hex file from the SILICON CHIP website (free for subscribers). Program the chip using a PICkit 3 or similar. You can use the PICkit 3 to power IC3 but be careful not to exceed its 3.6V maximum supply rating.

Ideally, it's a good idea to do some basic checks before connecting a battery. If you have a current-limited bench supply, set it to 12-24V at 10mA and connect it between pins 1 & 9 of CON1, with the negative terminal to pin 9. Once the on-board capacitors charge, the current drain should drop to just a few milliamps and the red LED should flash, indicating a battery is not detected.

If you don't have a bench supply, you can use any DC source with a series resistor of say 470Ω 0.5W for ~12V or 1kΩ 0.5W for ~24V.

Assuming all is OK, connect the battery, taking care to orientate the plug correctly as the header is not polarised. In theory, the unit should survive a reversed supply connection, at least in the short term, but the 10Ω resistors could potentially overheat as the parasitic diodes in Mosfets Q1-Q4 will conduct.

After a couple of seconds you should see the green LED flash once for each cell in the battery. If you have joined EN and CELL1 on CON2, depending on the battery voltage, the unit may then begin the balancing operation. Otherwise, it will go into sleep mode and both LEDs will remain off.

If driving the EN pin externally, wire this up to your charger so that it will be driven high during charging. You can then switch on the charger and check that the red and green LEDs illuminate together briefly, to indicate that the unit has "woken up". If the battery needs balancing, you will see further flashes.

When balancing occurs, green LED2 will flash rapidly and then switch off. The number of flashes indicates which cell is being shunted/discharged. Once the cells have been balanced, green LED2 will be switched on for around one second, then switch off.

Error indication

If an error condition is detected (eg, an unexpected low cell voltage), red LED1 will flash rapidly. If the EN pin drops below 0.95V while balancing is still active, red LED1 will switch on for around one second and then the unit will go back into sleep mode until the EN pin voltage rises again. SC

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$ave money: replace failed batteries in emergency lights

Recently a building owner I know had a problem with his emergency lights – you know the ones, where an exit route is illuminated to show the way out of the building in a blackout. When power goes out, an internal battery keeps the light on for some time.

by ROSS TESTER

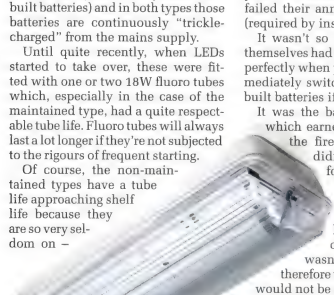
There are many different types of emergency lighting. The ones we're talking about here look just like standard fluoro fittings. In the electrical trade they're called luminaires and can be "maintained" and "non maintained".

The difference is that maintained emergency luminaires are "on at all times" – normally powered by the mains so they light an exit route 24 hours a day; whereas non-maintained fixtures only come on when power fails.

Neither type can be turned off (except by cutting mains power to them, usually at the switchboard – and even then they stay lit courtesy of their in-built batteries) and in both types those batteries are continuously "trickle-charged" from the mains supply.

Until quite recently, when LEDs started to take over, these were fitted with one or two 18W fluoro tubes which, especially in the case of the maintained type, had a quite respectable tube life. Fluoro tubes will always last a lot longer if they're not subjected to the rigours of frequent starting.

Of course, the non-maintained types have a tube life approaching shelf life because they are so very seldom on – they only light up in a blackout or other power-cut emergency (eg, a fire).



They look just like an "ordinary" fluoro lamp fitting.

While on the subject, there are other "emergency" lights often found in buildings which show either a running man and an arrow, showing the exit route, or simply the word "EXIT" if that's the way out.

Similarly, they're normally on but switch over to internal batteries in a blackout. There's yet another type with two tubes, one of which is powered by the mains and the other which comes on when the mains fails.

Now back to the building owner's quandary: of the half-dozen or so emergency luminaires in the twenty-year-old building, two had recently failed their annual "fire" inspection (required by insurance companies).

It wasn't so much that the lights themselves had failed, as they worked perfectly when power was on and immediately switched over to their in-built batteries if the power was cut.

It was the backup battery circuit which earned the big cross from the fire inspectors, as they didn't power the lights for the required 90 minutes without mains power.

Even though one lasted 45 minutes and one over an hour, that wasn't "up to spec" and therefore the building insurance would not be renewed without that vital certificate.

Never mind the fact that it was only a two-storey building, and maximum egress would be (at most) one minute. Them's the rules!

He contacted the electrician who looked after things electric in the building, asking if the luminaires could be repaired. He was told that they were never repaired; simply replaced with a new fitting.

Now I'm not saying that the building owner was named Scrooge McDuck, but he baulked at the quoted price of $295, plus GST. Each!

Fitting involved removing the old luminaire, mounting a new one, then re-wiring the mains. But as this also required mains power being disconnected, it could be quite inconvenient if done during working hours . . . and even more expensive if it had to be done after hours.

Being of a somewhat technical "bent", our hero reasoned that the backup supply must be a rechargeable battery and would be either a sealed lead-acid (SLA), nickel-cadmium (Nicad) or (possibly) nickel-metal-hydride (NiMH), presumably with a simple trickle charger running from the mains plus an inverter to boost the voltage back up to power the tubes when required.

Unless someone wasn't playing by Hoyle, such a battery should be significantly less than what the electrician quoted.

It was only a matter of a couple of minutes up a ladder with trusty screwdriver in hand to whip off the emergency light cover and his suspicions were confirmed – a "stick" of five C-sized NiCd batteries, shrink-wrapped and mounted on a plate, with a quick-connect terminal attaching them to the charger/inverter.

Indeed, there was even a label attached telling him that it was a 5-cell, 6V, 1000mAh Nicad.

While it would appear that the vast majority of emergency lights use NiCd batteries, they are not all the same. Indeed, within the same building there were about half with a 6V stick, made up of 5 "C" size Nicads, but the other half had four "D" size, or 4.8V (as seen in the photo above). We would hazard a guess that there may be other variations on the theme. However, when he asked Battery Business if this would cause any problems, the manager smiled and said "we can replace any battery for anything." Nuff said!

So one night when everyone had gone home, he turned off the appropriate lighting circuit at the switchboard and removed the cover/diffuser and the fluoro tubes (which of course was still lit). He then undid the two screws which held the Nicad stick in place. Carefully unplugging the stick (which was a very simple, ten second job) he replaced the tube and diffuser, then turned power back on.

Measuring the output voltage revealed that the voltage was less than the 7.5 or so volts he would have expected; in fact it was about 5.2V which does suggest one or more of the cells was at least a little sick!

Placing the battery on a suitable load showed that it had dropped markedly even after 15 minutes, so the stick definitely needed replacing.

A quick search on line revealed that these batteries were available but quite a bit more expensive than he expected – more than $100+. He was hoping for perhaps half that.

But one thing he did notice was a company called "Battery Business" who promised that they can replace any battery for anything.

He remembered seeing one of their outlets only a few streets away from his building – so much the better. They didn't quote any prices on line but it was worth the ask.

So next morning, on the way in, he called into Battery Business with the old unit.

The manager told him that if they didn't have it in stock, they'd simply make up new ones and shrink-wrap them to the old bases, then weld the old connectors on. The price? $40 each, including GST. That made him smile.

It turned out that they didn't have any in stock but it only took them a day to have the replacements made up. He duly picked them up – and noticed they even came with a similar label to the old one!

Fitting the replacement battery to the emergency light fitting was just as simple as removing the old one – screw it in, plug it in, replace the fluoro tubes and put the cover/diffuser back on.

As he put one of the fluoros in, it instantly came to life, indicating that they had supplied a charged battery. This was repeated for the second fitting.

With the power back on, he left them for a day or so, then after hours turned the power back off.

And after two hours they were still lighting the way, so he called the inspector who duly checked them for himself, passed them as A-OK and issued the insurance certificate.

So for just a few minutes work, both of the old emergency exit fittings were brought back to new condition (in fact, probably better-than-new, because he replaced all the tubes at the same time – to be sure, to be sure, etc), saving a bit of landfill but more importantly for him, saving several hundred dollars in the process. SC

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Please note: the SILICON CHIP PartShop does not sell kits; for these, please refer to kit supplier's adverts in this issue.

HMV Service Manual – Models 209/660

Consumption – 82W
Wave Length Range – 13.9 metres (21.57 megacycles) to 47 metres (6.38 megacycles). 187.5 metres (1600 kc) to 545 metres (550 kc).
Intermediate frequency – 457.5 kc.
Max. undistorted power output – 4.5 watts.
Loudspeaker – Model 290 uses an 8-inch speaker, the field winding of which acts as filter choke. DC resistance of (the) field coil cold is 1800 ohms. DC resistance of (the) voice coil is 2 ohms. At 400 cycles, impedance of voice coil is 2.35 ohms.
Valves – 6J8G. 6U7G, 6B8G, 6V6G, 5Y3G.

Circuit description

This model is a superheterodyne in which a 6J8G triode-hexode acts as frequency changer. The oscillator circuit is designed to provide relatively constant output voltage over the wide tuning range incorporated in this receiver. The 6J8G is band-pass coupled to a 6U7G which acts as an IF amplifier and which is in turn coupled to a 6B8G, the diodes of which are used as signal and AVC rectifiers respectively, the signal diode being tapped down one-third on the secondary of the IF transformer coupling these two tubes.

The amplifier section of the 6B8G acts as the first AF stage and is resistance-capacity coupled to the 6V6G output stage. AVC (automatic volume control) is applied to the 6J8G, 6U7G and 6B8G tubes.

The aerial coupling transformer on the broadcast band is a high efficiency, iron-cored type employing Litz-wire coils. The IF transformers also use Litz-wire coils and high-efficiency iron-dust cores. The coils are tuned by silver-coated titanium dioxide fixed condensers.

The oscillator circuit padding adjustment is carried out inductively on both bands by means of adjustable iron cores in the oscillator coils, while on the short-wave band a certain amount of equalisation of oscillator output at the low frequency end of the band is obtained by feedback across the 0.00054μF oscillator padding condenser; which feedback is introduced from the oscillator plate circuit by the 0.01μF condenser connected to the top side of the padding condenser. The padding condensers are held to a tolerance of ±1%.

Inverse feedback is applied to the complete audio system, through the Tone Monitor Control from the secondary of the output transformer to a tap on the volume control. In this manner, the whole of the audio system benefits from the distortion reducing properties of the negative feedback system. In addition the circuits associated with the Tone Monitor Control provide selective feedback varying with frequency, thus providing control of tonal balance. Furthermore, the degree of feedback varies with the setting of the volume control in such a way as to provide the best response for both local and distant reception at all volume levels.

The speaker field winding placed in the negative HT line is used as a filter choke in conjunction with two 16μF wet-type electrolytic condensers, one of which is a regulating type which automatically prevents the rise of voltage beyond a safe limit during the warming-up period.

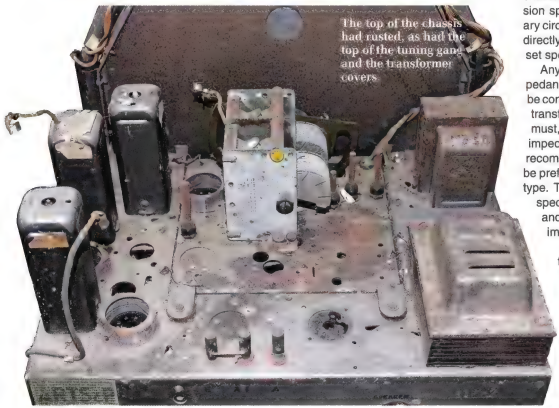
Note: it is essential that the positions of these two condensers in the circuit shall not be inter-changed. These condensers are mounted on the speaker and are thus protected from damage should the power be accidentally switched on while the speaker is out of circuit. A voltage divider is placed across the field to obtain the required bias for RF circuits.

Jacks are provided at the back of the chassis for the connection of an extension speaker. They are in the secondary circuit of the output transformer and directly in shunt to the voice coil in the set speaker.

Any speaker having a voice coil impedance between 2.5 and 4 ohms can be connected to these jacks (the output transformer on the extension speaker must, of course, be first removed). An impedance of 3 ohms at 400 cycles is recommended and the speaker should be preferably of the permanent magnet type. The HMV extension speaker is specially designed for this purpose and has, in addition, its own constant impedance volume control.

The core of the output transformer is internally connected to the positive HT line to prevent corrosion troubles.

Band switching is carried out by means of a single-deck switch. The oscillator primary coils are connected in series and not switched. Capacitive feedback is applied across the



The top of the chassis had rusted, as had the top of the tuning gang and the transformer covers.

padding condenser on the short-wave band and this is switched by contacts on the wave-change switch.

The first position of the switch (extreme anti-clockwise) connects the short-wave and associated components, and the second position the broadcast circuits. Only the broadcast band dial lamp circuit is switched, being cut out when the wave-change switch is in the short-wave position. See that when in the broadcast position, both wave bands are illuminated, while in the short-wave position, only the short-wave band is illuminated.

Tone Monitor: this is a four-position switch. The following effects are secured in the various switch positions:

1st Position (Wide Range): normal bass response and treble boosted to compensate for side-band attenuation for highest fidelity.

2nd Position (Normal): normal bass and small degree of treble cut for normal and long-distance reception.

3rd Position (Bass): as in "Normal" position, but additional treble cut for reduced background noise and particularly for pick-up operation.

4th Position (Speech): boosted treble response and bass cut for improved intelligibility of speech.

Note: the RF trimmers on this model are of a plunger type with air dielectric, and possess exceptionally high stability and efficiency. A special adjusting tool can be obtained from the factory, incorporating a box spanner for the condenser lock nut and an adjusting hook for the plunger.

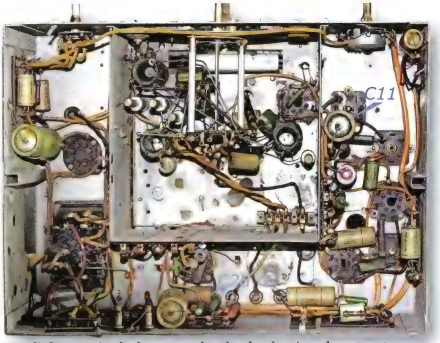
After loosening the lock nut at the top of the condenser, the adjusting hook is inserted in the hole which will be found in the top of the plunger, which can then be easily adjusted by moving up or down as required with a slight rotary movement. When adjustment is completed, tighten the lock nut securely.

Author's comments

(1) The RF trimmers referred to above are the four metal rods adjacent to the tuning gang;

(2) Litz wire is designed to reduce the skin effect and proximity effect losses in conductors used at frequencies up to about 1 MHz.

(3) The current use of Hertz (Hz) for frequency officially replaced "cycles" in 1960 but only became widely accepted in the 1970s.

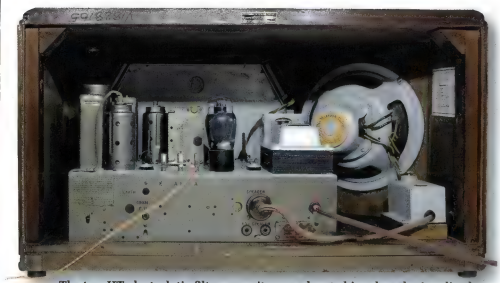


Very little corrosion had penetrated under the chassis and most parts were still in good condition. Capacitor C11 (labelled) had failed though, while C28 operates at high voltage and was replaced as a precaution.

This view shows the chassis after it had been cleaned and painted to stop further corrosion.

Everything appeared to be in good condition under the chassis. However, the original figure-8 mains flex was still in place, so this was replaced with 3-core mains cable so that the chassis could be securely earthed.

One point of interest is that HMV recommended swapping around the Active and Neutral connections to the transformer to determine if one set of



The two HT electrolytic filter capacitors are located in a box that's spliced into the speaker cable. These capacitors had previously been replaced, as had electrolytic capacitors C11 & C29.

connections generated less hum. This recommendation is displayed on a label inside the cabinet (see Fig.2).

The two HT filter electrolytics (C34 & C35) are located in a box spliced into the speaker cable and had previously been replaced, as had electrolytic capacitors C11 & C29. No other component replacements were evident and the under-chassis parts all checked OK.

By contrast, the four 6.3V dial lamps had all gone dark and checking revealed that they had all gone open circuit. These were replaced and the set then powered up without the valves in place while some initial checks were made. The power consumption remained at a steady 14W and the mains transformer remained cool.

The valves were then refitted and my optimism that it would work was rewarded when the radio was powered up. However, while it sounded quite reasonable, its 105W power consumption was uncomfortably above the specified 82W. A quick check with the power switched off revealed that the 0.5μF AVC (AGC) bypass capacitor (C11) was hot. Replacing this immediately reduced the power consumption to 82W, exactly as specified.

As a precaution, I also replaced

This view shows the front of the chassis and the dial prior to restoration. Despite its unusual shape, the large dial scale is easy to read.

This speaker coil cover from another HMV radio illustrates how HMV re-badged the Rola speaker used in the model 209 and other sets.

capacitor C28 which feeds the audio signal from the anode of the 6B8 to the grid of the 6V6 output stage. The original capacitor was still performing faultlessly but this part operates at high voltage, so replacing it is a good idea in order to guard against short-term failure.

Cabinet restoration

This part of the restoration initially involved sanding the cabinet back to bare timber using aluminium oxide grade 80 abrasive paper. This type of abrasive is particularly good for this job, since it doesn't tend to clog with the removed debris.

When using coarse abrasive, it is essential not to cut across the grain. In addition, a smooth finish relies on careful sanding of the polyurethane coatings that are applied, rather than fine sanding the bare timber.

The black highlights in the cabinet were painted with acrylic paint after the first sealing coat. This prevents the black paint from running into the adjoining wood grain by capillary action.

Multiple coats of Cabot's CFP clear gloss finish were then applied, with sanding between coats. The gloss was a personal choice; the cabinet originally had a satin finish.

Another problem was that the original celluloid dial cover had yellowed. This was replaced with a clear dial cover fabricated from thermo-moldable PETG plastic.

The performance of this set illustrates the value of buying a quality radio back in 1939. It had few failures and now, fully restored, continues as an object of beauty and function. SC

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03/16

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MINIMAXIMITE	NOV 2011	07111111	$10.00
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HIGH TEMPERATURE THERMOMETER MAIN PCB	MAY 2012	21105121	$30.00
HIGH TEMPERATURE THERMOMETER Front & Rear Panels	MAY 2012	21105122/3	$20 per set
MIX-IT! 4 CHANNEL MIXER	JUNE 2012	01106121	$20.00
PIC/AVR PROGRAMMING ADAPTOR BOARD	JUNE 2012	24105121	$30.00
CRAZY CRICKET/FREAKY FROG	JUNE 2012	08109121	$10.00
CAPACITANCE DECADE BOX	JULY 2012	04106121	$20.00
CAPACITANCE DECADE BOX PANEL/LID	JULY 2012	04106122	$20.00
WIDEBAND OXYGEN CONTROLLER MK2	JULY 2012	05106121	$20.00
WIDEBAND OXYGEN CONTROLLER MK2 DISPLAY BOARD	JULY 2012	05106122	$10.00
SOFT STARTER FOR POWER TOOLS	JULY 2012	10107121	$10.00
DRIVEWAY SENTRY MK2	AUG 2012	03107121	$20.00
MAINS TIMER	AUG 2012	10108121	$10.00
CURRENT ADAPTOR FOR SCOPES AND DMMS	AUG 2012	04108121	$20.00
USB VIRTUAL INSTRUMENT INTERFACE	SEPT 2012	24109121	$30.00
USB VIRTUAL INSTRUMENT INT. FRONT PANEL	SEPT 2012	24109122	$30.00
BARKING DOG BLASTER	SEPT 2012	25108121	$20.00
COLOUR MAXIMITE	SEPT 2012	07109121	$20.00
SOUND EFFECTS GENERATOR	SEPT 2012	09109121	$10.00
NICK-OFF PROXIMITY ALARM	OCT 2012	03110121	$5.00
DCC REVERSE LOOP CONTROLLER	OCT 2012	09110121	$10.00
LED MUSICOLOUR	NOV 2012	16110121	$25.00
LED MUSICOLOUR Front & Rear Panels	NOV 2012	16110122	$30 per set
CLASSIC-D CLASS D AMPLIFIER MODULE	NOV 2012	01108121	$30.00
CLASSIC-D 2 CHANNEL SPEAKER PROTECTOR	NOV 2012	01108122	$10.00
HIGH ENERGY ELECTRONIC IGNITION SYSTEM	DEC 2012	05110121	$10.00
USB POWER MONITOR	NOV 2012	04109121	$10.00
1.5kW INDUCTION MOTOR SPEED CONTROLLER (NEW V2 PCB)	DEC 2012	10105122	$35.00
THE CHAMPION PREAMP and 7W AUDIO AMP (one PCB)	JAN 2013	01109121/2	$10.00
GARBAGE/RECYCLING BIN REMINDER	JAN 2013	19111121	$10.00
2.5GHz DIGITAL FREQUENCY METER – MAIN BOARD	JAN 2013	04111121	$35.00
2.5GHz DIGITAL FREQUENCY METER – DISPLAY BOARD	JAN 2013	04111122	$15.00
2.5GHz DIGITAL FREQUENCY METER – FRONT PANEL	JAN 2013	04111123	$45.00
SEISMOGRAPH MK2	FEB 2013	21102131	$20.00
MOBILE PHONE RING EXTENDER	FEB 2013	12110121	$10.00
GPS 1PPS TIMEBASE	FEB 2013	04103131	$10.00
LED TORCH DRIVER	MAR 2013	16102131	$5.00
CLASSIC DAC MAIN PCB	APR 2013	01102131	$40.00
CLASSIC DAC FRONT & REAR PANEL PCBs	APR 2013	01102132/3	$30.00
GPS USB TIMEBASE	APR 2013	04104131	$15.00
LED LADYBIRD	APR 2013	08103131	$5.00
CLASSIC-D 12V to ±35V DC/DC CONVERTER	MAY 2013	11104131	$15.00
DO NOT DISTURB	MAY 2013	12104131	$10.00
LF/HF UP-CONVERTER	JUN 2013	07106131	$10.00
10-CHANNEL REMOTE CONTROL RECEIVER	JUN 2013	15106131	$15.00
IR-TO-455MHZ UHF TRANSCEIVER	JUN 2013	15106132	$7.50
"LUMP IN COAX" PORTABLE MIXER	JUN 2013	01106131	$15.00
L'IL PULSER MKII TRAIN CONTROLLER	JULY 2013	09107131	$15.00
L'IL PULSER MKII FRONT & REAR PANELS	JULY 2013	09107132/3	$20.00/set
REVISED 10 CHANNEL REMOTE CONTROL RECEIVER	JULY 2013	15106133	$15.00
INFRARED TO UHF CONVERTER	JULY 2013	15107131	$5.00
UHF TO INFRARED CONVERTER	JULY 2013	15107132	$10.00
IPOD CHARGER	AUG 2013	14108131	$5.00
PC BIRDIES	AUG 2013	08104131	$10.00
RF DETECTOR PROBE FOR DMMs	AUG 2013	04107131	$10.00
BATTERY LIFESAVER	SEPT 2013	11108131	$5.00
SPEEDO CORRECTOR	SEPT 2013	05109131	$10.00
SIDRADIO (INTEGRATED SDR) Main PCB	OCT 2013	06109131	$35.00
SIDRADIO (INTEGRATED SDR) Front & Rear Panels	OCT 2013	06109132/3	$25.00/pr
TINY TIM AMPLIFIER (same PCB as Headphone Amp [Sept11])	OCT 2013	01309111	$20.00

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
AUTO CAR HEADLIGHT CONTROLLER	OCT 2013	03111131	$10.00
GPS TRACKER	NOV 2013	05112131	$15.00
STEREO AUDIO DELAY/DSP	NOV 2013	01110131	$15.00
BELLBIRD	DEC 2013	08112131	$10.00
PORTABL-D MAIN BOARDS	DEC 2013	01111131-5	$35.00/set
(for CLASSIC-D Amp board and CLASSIC-D DC/DC Converter board refer above (Nov 2012/May 2013))			
LED Party Strobe (also suits Hot Wire Cutter (Dec 2010))	JAN 2014	16101141	$7.50
Bass Extender Mk2	JAN 2014	01112131	$15.00
Li'l Pulser Mk2 Revised	JAN 2014	09107134	$15.00
10A 230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102141	$12.50
NICAD/NIMH BURP CHARGER	MAR 2014	14103141	$15.00
RUBIDIUM FREQ. STANDARD BREAKOUT BOARD	APR 2014	04105141	$10.00
USB/RS232C ADAPTOR	APR 2014	07103141	$5.00
MAINS FAN SPEED CONTROLLER	MAY 2014	10104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16105141	$10.00
HYBRID BENCH SUPPLY	MAY 2014	18104141	$20.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00
TOUCHSCREEN AUDIO RECORDER	JUL 2014	01105141	$12.50
THRESHOLD VOLTAGE SWITCH	JUL 2014	99106141	$10.00
MICROMITE ASCII VIDEO TERMINAL	JUL 2014	24107141	$7.50
FREQUENCY COUNTER ADD-ON	JUL 2014	04105141A	$15.00
VALVE SOUND SIMULATOR PCB	AUG 2014	01106141	$15.00
VALVE SOUND SIMULATOR FRONT PANEL (BLUE)	AUG 2014	01106142	$10.00
TEMPMASTER MK3	AUG 2014	21108141	$15.00
44-PIN MICROMITE	AUG 2014	24108141	$5.00
OPTO-THEREMIN MAIN BOARD	SEP 2014	23108141	$15.00
OPTO-THEREMIN PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
ACTIVE DIFFERENTIAL PROBE BOARDS	SEP 2014	04107141/2	$10/SET
MINI-D AMPLIFIER	SEP 2014	01110141	$5.00
COURTESY LIGHT DELAY	OCT 2014	05109141	$7.50
DIRECT INJECTION (D-I) BOX	OCT 2014	23109141	$5.00
DIGITAL EFFECTS UNIT	OCT 2014	01110151	$15.00
DUAL PHANTOM POWER SUPPLY	NOV 2014	18112141	$10.00
REMOTE MAINS TIMER	NOV 2014	19112141	$10.00
REMOTE MAINS TIMER PANEL/LID (BLUE)	NOV 2014	19112142	$15.00
ONE-CHIP AMPLIFIER	NOV 2014	01109141	$5.00
TDR EXPLORER	DEC 2014	04112141	$5.00
MULTISPARK CDI FOR PERFORMANCE VEHICLES	DEC 2014	05112141	$10.00
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$50.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111144	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30/set
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015		$25.00
ISOLATED HIGH VOLTAGE PROBE	JAN 2015	04108141	$10.00
SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
LOW-FREQUENCY DISTORTION ANALYSER	APR 2015	04104151	$5.00
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	04105151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04105152/3	$20.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7.50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
9-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	15108151	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16102161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50

NEW THIS MONTH

BATTERY CELL BALANCER	MAR 2016	11111151	$6.00
DELTA THROTTLE TIMER	MAR 2016	05102161	$15.00

LOOKING FOR TECHNICAL BOOKS? YOU'LL FIND THE COMPLETE LISTING OF ALL BOOKS AVAILABLE IN THE SILICON CHIP ONLINE BOOKSTORE – ON THE "BOOKS & DVDs" PAGES AT SILICONCHIP.COM.AU/SHOP

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Shopping for a Class-D amplifier

I have been shopping for an inexpensive amplifier as part of my DVD surround sound system. The amplifier of interest is a Class-D amplifier. Places like eBay and Banggood are selling Class-D amplifier modules for between $13 and $30, with power output between 3W and 100W per channel. You can purchase a mono, stereo, 2.1 channel and even a 5.1 channel module. The specifications include a THD of less than 0.1% and a frequency response between 20Hz and 20kHz.

While I could find a locally-made suitable power supply for a 2-channel amplifier, for example a 15-20V 150W laptop power supply for less than $50, what if you want a power supply for a 5.1 channel module? The answer would require a power supply that can handle more current than a laptop's power supply. The other reason is whether the "heavy duty" power supplies at 15V-20V purchased from overseas meet Australia's technical standards. (A. P., via email).

- High-power commercial DC supplies are available but a 150W amplifier will probably need more than 20V. We have published a number of Class-D power amplifiers, the most recent being a 10W/channel design in September 2014 and a high-power design in November & December 2012, together with a suitable power supply circuit.

For a high-power Class-D amplifier, you really need a loudspeaker protector as a catastrophic fault in the amplifier would destroy the loudspeakers. A suitable protector circuit was described in these two articles.

Even if you were not going to build our Class-D amplifier, we would still strongly recommend a Protector circuit and in that case the best solution would be the Universal Protector featured in the November 2015 issue.

Gate closer using a wiper motor

Many years ago, you produced an article for a gate closer using a windscreen wiper motor. Please advise if I can purchase a copy of this project or any other similar one. (F. H., via email).

- You can see a 2-page preview of the wanted article at www.siliconchip.com.au/Issue/1997/August/Remote+Controlled+Gates+For+Your+Home

You can purchase the full digital issue or a print-out of the article itself from our Online Shop

Wire glue not for high current connections

I recently located Jaycar's "Wire Glue" (Cat. NM2831) product in their catalog and thought it may be of use in the simpler projects that I find in the magazine.

Is the glue designed to be used to make only temporary repairs to an electronic device until it can be properly soldered/re-soldered or can it be used for more substantial and long term purposes in projects, etc? Could this glue be used to replace soldering in any of your existing (simple) projects and might you consider using this glue as a solder replacement in any of your future simple projects? (P. M., Karrabar, NSW).

- Our reading suggests that this glue would probably be OK for connections where low resistance or a high current

Fingerprint Access Controller Problems

I built the Fingerprint Access Controller project from the November 2015 issue and I am having all manner of problems with it. Firstly, do you need to have the actual scanner module connected to the controller for it to display anything on the LCD? I have been over the board many times. All components are present and accounted for, in their correct positions, and all solder joints are good.

I have all the correct voltages where they should be, with and without the PIC and LCD in place. I replaced the LCD just in case and even tried replacing the PIC16F88 with a programmed unit from Silicon Chip, just in case my PICkit 3 or computer is faulty. I've checked all tracks on the PCB have continuity and measured all capacitor values and ESR.

If I apply power with the PIC16F88 in its socket, all voltages are correct. I get two rows of square blocks on the LCD until I adjust the contrast pot and then they disappear. If I then remove the power and re-apply it, the top lefthand character on the LCD flashes on and then disappears to reveal a blank LCD. I have also noticed that the backlight is coming on whilst the PIC is in its socket but not when it is out.

I am at a loss to explain why all this is happening unless I need to have the actual scanner module connected, which I am still waiting to arrive. Any help would be much appreciated. (P. C., via email).

- The display should show the correct characters once you power up with the fingerprint module connected. The program within the PIC will stall if the fingerprint module is not connected, as it waits for a response from the module at the beginning of the program sequence.

Unless there is a response from the fingerprint module, there will be no data sent to drive to the display with characters.

The LCD backlight is switched under control by the PIC so the backlight will not light up with the PIC out of circuit.

connection is not required. However, we don't know how permanent these "glue" connections would be.

In summary, if you need to make a non-critical connection when you don't have a soldering iron available (or maybe you require connection to some metal, eg, aluminium, which cannot be easily soldered), then "Wire Glue" is probably worth trying.

Parts queries for 6-digit LED clock

I am building the High-Visibility 6-Digit LED GPS Clock project as featured in the December 2015 & January 2016 issues of SILICON CHIP. However, I am having trouble finding a couple of the parts as the 47-100kΩ LDR and the 3.3V infrared receiver. I've found several suppliers have 5V infrared receivers but not a 3.3V receiver. In addition, Jaycar have a 48-140kΩ LDR. Will this suit? (P. C., via email).

● The Altronics Z1611A infrared receiver is rated for operation at 3-5V. The Jaycar part isn't (5V only) however it's possible it will work anyway. We haven't tried it.

The specification for a 47-100kΩ LDR was intended to suggest that an LDR with a nominal resistance that overlaps that range should be suitable, hence we expect the Jaycar part should work fine, especially as the clock software has automatic calibration for the LDR.

If you use the Jaycar LDR and find it doesn't work well (unlikely), you could always change or shunt the 10kΩ resistor from the supply rail to compensate, ie, increase its value if using an LDR with a higher nominal resistance or lower the resistor value for a lower-value LDR.

Giant LED clock works well

Just dropping you a quick note to say thanks for the giant LED clock. I really enjoyed putting it together. The software with the supplied PIC from SILICON CHIP has a few differences as described in the articles. I note there are two extra options, "HTAL" and "GPSLoc" and pushing the show date button twice shows the day of week.

What do the other two options do? Further, mine doesn't show GPS 00 and counting up it just shows flashing 12:00:00 and then after the acquisition time it switches to the correct time. Just curious; very happy with the way it is. (M. B., via email).

● The "HTAL" (actually meant to be "XTAL") allows the RTCC to be trimmed to compensate for any error in the 32.768kHz crystal frequency. If you are using a GPS unit with a 1PPS output, this is done automatically, to avoid the need for the RTCC to be corrected in whole-second steps. We're rather proud of this solution actually. What it does is it slowly decreases the RTCC "speed" by reducing the crystal trim value until the 1PPS pulses start coming before the RTCC tick-over.

It then increases the trim value until the situation reverses and basically "dithers" the trim to keep the RTCC and GPS synchronised. You'd never notice it as it's only changing tiny fractions of a second but it should avoid the need to ever actually correct the time except during DST changes.

If no GPS is fitted, then XTAL trim can be used to manually adjust the LED clock to match a known-accurate clock.

The GPSLOC setting is something we realised would be useful quite late. We had assumed that the data from the GPS unit would be unusable until the GPS unit indicated it had a good fix. Due to our metal roof and depending on the weather etc, sometimes we are not able to get a good fix, so we decided to see what would happen if the code was changed to use the data from the GPS unit regardless of whether it had a good fix.

It seemed to give accurate time anyway, although perhaps not quite as accurate. The GPSLOC setting allows you to tell the clock to ignore the "fix good" indicator and just use the data from the GPS unit as soon as it has enough information to get the time (ie, UTC time, latitude and longitude). Basically, you'd only change this setting if you had trouble getting a reliable GPS fix.

Your clock probably doesn't show the "GPS 00" display because the module doesn't send much useful data until it has a good fix – or maybe it just gets a fix really quickly. Once the module is "warm" that's what tends to happen. With some modules though, if the signal is poor and it takes a while to get a fix, it will trigger the GPS progress display.

Switching transistor question

I have a question about the Giant LED Clock project. The silk screen is not in agreement with the circuit diagram or the parts list, regarding what type of transistor goes where . . . all very confusing and frustrating. I have mounted Q1-Q9 as BC337 but the cir-

How About A Valve RIAA Preamplifier?

With respect to your Valve Preamplifier project featured in the January & February 2016 issues, it is good to know that Altronics are going to do a kit. Have you considered designing an RIAA preamplifier along these lines as well?

Some time ago, I modified one of your earlier designs that used a separate power supply and two preamp PCBs (SILICON CHIP, November 2003 & February 2004). It was a little cumbersome but it did work OK.

A design all on one board would be great. What do you think? (K. C., via email).

● It may be feasible to design an RIAA version of the valve preamplifier but we are concerned that there may not be enough open-loop gain to ensure correct equalisation at the very low bass frequencies. And even if there is sufficient open-loop gain, there will be very little more to provide distortion reduction.

We are also concerned that the signal-to-noise ratio would be very poor. The existing valve preamplifier has an S/N ratio of -105dB with respect to 1V. When referred to a 2mV signal, that will be reduced by 54dB to -51dB and that is not allowing for the almost 20dB boost at low bass frequencies. On that basis, such a preamplifier is likely to be unusable.

Yes, we know that there are RIAA valve preamplifiers to be seen on the internet but unless they have changes the laws of physics, we cannot see how they could be satisfactory. If you want to listen to records via valves, use a good (SILICON CHIP) RIAA preamplifier and follow it with the valve preamplifier or valve amplifier.

Stereo DAC Won't Handle 96kHz Signals

I recently purchased and built the High Quality Stereo Digital-to-Analog Converter kit from Altronics in Perth. It is based of the September-November 2009 SILICON CHIP articles.

I am having some noise problems with the DAC kit on quiet passages at the start and end of songs. I am hearing a rapid quiet popping noise when using the optical inputs with a 96kHz or 192kHz sampling rate, although I think I might have also heard the sounds when using a coaxial input. The issue seems to be worse when using a PS3 or PS4 but on my PC's optical output, it's less of an issue.

These popping sounds do not occur if I put the signal through my sound card's S/PDIF input, so I've isolated the issue to the DAC. It also means that the devices I'm experiencing the issues on don't cause any issues on other receivers.

The notes and errata mention changing the 33pF capacitors at pins 1 & 2 of the optical receivers to 100pF. This, however, actually made things worse for me. Reducing those capacitors' value seems to have made some improvement but it still didn't resolve the problem completely. I have tested with smaller capacitors down to 1.5pF but ended up removing them altogether. It still has some noise but it is reduced to the occasional pop.

Is it safe for me to remove these capacitors? What is their purpose?

Looking at the circuit design, I'm a bit confused about the implementation of the optical input. I looked at the data sheet for the Altronics optical receiver and it shows a sample implementation with a bypass capacitor and series 47µH inductor for pin 3, however there is no such inductor in your particular design. Should I try adding these inductors? I note that the CLASSiC DAC design uses those inductors.

If you have any tips to resolve the popping sound issue, it would be very much appreciated. (T. K., via email).

● We believe it is safe to remove those capacitors. The DAC was originally designed to use Jaycar Toslink receivers which recommended those capacitors in the data sheet. Presumably they were intended to improve noise immunity however as you've found, they seem to make matters worse instead.

We're not sure how much inductors would help however they might reduce noise in the power supply. You could try cutting the supply tracks and soldering one in series for each receiver. Unfortunately, Jaycar seem to have stopped selling the Toslink receivers we used originally so you may not be able to get these to try.

Have you tried moving the DAC away from any sources of electrical noise? It may also be worth putting a ferrite sleeve around the power cable to the unit to prevent high frequency interference from coupling inside. Your problem could be due to interference from other equipment or inadequate supply bypassing/filtering for the receiver modules.

You could also try replacing the bypass capacitors for the optical receivers with higher value ceramic types, eg, 1µF (ideally X7R dielectric or similar).

cuit specifies BC547, disagreeing with the parts list (BC337).

I am worried that my board is now ruined, as to remove nine transistors without damaging the tracks may be a tall order. (G. M., via email).

● The circuit diagram and overlay diagrams published in the December 2015 issues should be followed to build the clock. If Q1-Q9 have been fitted as BC337, leave it that way and just use BC337s throughout. The main reason for specifying the BC547s was to save a little money.

Sorry about the confusion. We published errata in the February 2016 issue.

Alternative strobe disc suggestions

With reference to your white LED strobe and strobe disc presented in the December 2015 issue, old turntable AC frequency stroboscopes had limitations that need not limit a design based upon a microcontroller.

Since you use a quartz crystal to generate the timebase, why bother with multiple strobe patterns and a single strobe speed when you could easily generate three accurate strobe speeds and use a simple single bar set for the strobe pattern?

With a pushbutton and pull-up resistor to re-purpose the GP2 pin, and eliminating the JP1 jumper, you could switch the frequencies in software. The spare GP1 pin, for example, could drive a LED and resistor to flash a simple pattern to show which strobe rate was active.

With a 90-bar strobe pattern, for example, wouldn't generating accurate flash rates of 50, 67.5 and 117Hz be a doddle, particularly if the crystal was 3.2768MHz? (K. S., via email).

● There are many ways to produce a suitable strobe but we wanted to be able to have a strobe light that was compatible with existing strobe discs, and particularly those turntables with strobe markers arranged around the rim of the platter.

While a LED could have been used to indicate different strobe rates selected with a pushbutton, a simple jumper link that's either in or out is all that's required for 100/120Hz selection.

Design for a 6V CDI system wanted

I'm looking for a CDI I can build for an old 1970s Ariel Arrow 2-stroke motorbike engine. I've downloaded an article and circuit drawings from your website, based on a 1997 design. My problem is that the Arrow has a 6V electrical system, so what modifications would be needed to convert this to 6V? (S. W., via email).

● Unfortunately, none of our inverter based CDI designs can be easily changed to 6V operation since the inverter driver ICs will not work at that low voltage. The "Replacement CDI For Small Petrol Motors" (SILICON CHIP, May 2008) may suit your bike if there is a high-voltage generator included on the bike itself.

A 6V CDI was published in the November 1971 issue of *Electronics Australia*. Its inverter was a free-running

Notes & Errata

Loudspeaker Protector, October 2011 & Universal Loudspeaker Protector, November 2015: both articles refer to a 70°C thermal cut-out from Jaycar, Cat. ST3831. This is incorrect, the correct catalog number is ST3833.

High-Visibility 6-Digit LED GPS Clock, December 2015-January 2016: two bugs have been identified in the firmware. One causes the unit to display the incorrect time for 8pm and later when set to 12-hour mode. The other causes minutes to be shown as 60 rather than 00 for one minute if the current time zone has an offset that is not a whole number of hours.

Firmware v1.2 (revision C) fixes both problems and is available for download from our website. Affected users can send their PIC32 chips back in to be re-programmed if they are unable to do so themselves.

In addition, in Pt.2, the instructions for gluing the case together state "The front panel is rotationally symmetrical so its orientation is not important . . .".

While the front panel is rotationally symmetrical, it does not have mirror symmetry so it is possible to glue it "flipped" such that the LED colons will slant in the wrong direction. Please pay attention to this possibility while assembling the case.

QuickBrake, January 2016: The voltage applied to the reset pin of 7555 timer IC3 once the timing capacitor has charged may not reach a sufficient level to release the reset. To solve this, change the 220kΩ resistor between pin 4 of IC3 and the 5V supply to 82kΩ.

In addition, trimpot VR1 is shown incorrectly orientated in the circuit diagram (Fig.1). Clockwise rotation reduces the resistance and thus reduces sensitivity, as stated in the text.

Ask SILICON CHIP

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minimal heat in the 10Ω resistors. A higher frequency could reduce saturation time in the windings.

USB power injector for STB HDD

The USB Power Injector featured in the January 2016 issue has caught my interest. I am wondering if this simple circuit would be suitable for use in powering an external HDD (up to 500GB) for a Dick Smith (DSE) Set Top Box [DSE codes "GH5930" & "GH5944" – I have one of each and my Dad has two of the earlier model (the GH5930)].

According to the manuals, it would appear that both of these units may be able to handle a USB drive of "up to" 500GB (the GH5944 up to 2TB) with a supplementary power supply and, if necessary, reformatted to FAT32. Would you agree with this proposition? (P. M., via email).

● Yes, the USB power injector should be suitable for the external hard drive. Power capability is dependent on the 5V supply so it needs to be rated for the hard drive's current drain. SC

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Ask SILICON CHIP

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Dog silencer overheats

I built the Dog Silencer (SILICON CHIP, July 1999) from an Oatley Electronics kit but I'm having trouble with it. The MTP3055 Mosfets on the output amplifier have 1W 10Ω resistors on their drains which keep overheating and I can't see why.

I replaced the Mosfets and disconnected the output transformers so there is no load and still the resistors cook. The output transformers get hot too. It's a simple circuit and shouldn't be a problem so any help you can give us would be appreciated as the dogs just keep on barking. (T. D., Perth, WA).

● Try connecting a 1N5819 Schottky diode across each transformer primary with the cathode to 12V and the anode to the junction of the 10Ω resistor and the transformer winding. The diode will clamp the back-EMF rather than the 10Ω resistor via the Mosfet. Also, the frequency could be adjusted for

500VA Transformer For CLASSiC-D Amplifier

As a part of our university project, I recently purchased CLASSiC-D amplifier kit and power supply kit. As the article says, we need a 300VA, 40-0-40V toroidal transformer. Can we use a 500VA 35-0-35V or 40-0-40V unit? And if we use 35-0-35V, does only ZD6 need to be changed to 33V or do we need need to change all the resistors (R_F, R2A, R2B, R3A, R3B, R4, R5, R6, R7, R8, R9 & R10) and zener diodes ZD5 & ZD6, as shown in the table? (J. J., via email).

● Yes, you can use a 500VA transformer. If building a stereo amplifier, it would allow you to get a continuous output rating of 200W or more per channel into 4-ohm loads, while the specified 300VA transformer would limit you to about 120W per channel on a continuous basis. The only disadvantages of using a 500VA transformer are size, weight and cost.

You certainly could use 35-0-35V but then you might not be able to get the rated power. It would come close, however. If doing this, you should change ZD6 to 33V, to prevent premature under-voltage cut-out.

Because the difference in the DC supply rails between 35V and 40V transformers is relatively small (~55V vs ~48V), you could probably get away without changing the other component values. However, doing so might have some benefits.

We suggest the following:

R_F: leave it at 4.3kΩ
R2A,R2B,R3A,R3B: 3.9kΩ 1W
R4: 39kΩ
R5: 2.7kΩ
R6: leave at 6.8kΩ
R7: leave at 8.2kΩ
R8: 2.0kΩ
R9: 6.8kΩ
R10: 680Ω 1W
ZD5: 56V 1W
ZD6: 33V 1W

oscillator based on two 2N3055 NPN transistors driving a pot-core transformer which would now be very difficult to obtain. However, you could possibly produce a suitable transformer, with suitable primary and secondary turns, using the transformer core featured in our most recent CDI, in the December 2014 and January 2015 issues.

You can order a reprint of the *Electronics Australia* CDI article from our website at www.siliconchip.com.au

Alternatively, you could use a standard (ie, non-CDI) ignition such as our High-Energy Ignition System in the November & December 2012. This can be run at 6V.

Raspberry Pi set-up hiccup

The Raspberry Pi temperature sensor articles in the January & February 2016 issues are fantastic projects! It has everything – a fast processor, good programming capability, WiFi, headless operation, sensor cards and more – wow! It's several orders of magnitude better than a PICAXE.

I bought the WiFi starter pack from Wiltronics. Initially, the WiFi did not work but after running the "update" and "upgrade" commands and rebooting the RPi, it then worked fine.

I am currently stuck on Step 8, "Connect the Sense HAT". When I run the `sudo pip-3.2 install pillow` command I get this error:

```
File "/home/pi/build/pillow/setup.py",
line 516, in build_extensions
(f, f))
ValueError: jpeg is required unless ex-
plicitly disabled using --disable-jpeg,
aborting
```

Then when I run the Python module as per your article I get the following error:

```
ImportError: No module named PIL
```

Could you offer any guidance as to what might be happening? Keep up the good work. (L. B., Thornleigh, NSW).

● The error message you received is explained at this link: www.raspberrypi.org/forums/viewtopic.php?t=130745&p=875524#p872657

To solve it, run this command:

```
sudo apt-get install libjpeg-dev
```

You should then be able to install Pillow. We didn't have to do this with the version of Raspbian we used but it looks like it may be necessary for other versions. (Reader feedback: that did the trick).

Problem with reluctor-based ignition system

I have just found and built the May 1990 High-Energy Ignition for Reluctor Distributors. I have a Toyota distributor, from a Toyota 5 FSE motor. It has two reluctor coils. I suspect the top one is for cylinder 1 sensing but the one below is a mystery to me. The lower shaft has four poles but the upper one has only one.

I have measured the output of both upper and lower coils with a DVM and their outputs seem to be about 300-400mV. When I connect these coils to the ignition module, the LED does not flash at all. It seems that the LED and the Darlington Transistor are always on.

What have I done wrong? (M. S., via email).

● The reluctor output is too low for the ignition module to work. The output from the reluctor needs to be several volts rather than 300-400mV.

Generally, a reluctor will deliver up to 30V peak when the engine is running. Check that you have the correct wires connected and that they are of the correct polarity.

Jacob's Ladder IGBT gets too hot

I assembled one of your Jacob's Ladder kits (SILICON CHIP, February 2013) and it worked fine. However, I soon burned out the Q1 IGBT. I replaced it and have noticed that after even a few seconds of use, it becomes red hot.

The voltage regulator is doing its job as everything checks out around 5V so I am unsure as to why this would be happening. Any ideas or suggestions? Can the part be substituted for something else? (D. B., via email).

● We suspect that you have the dwell period set too long. The dwell should be set to its minimum and then slowly advanced so there is sufficient sparking for the ladder but without overheating the IGBT.

The dwell is set using VR1. If this does not change the spark intensity, check that the trimpot (with the ignition coil disconnected) varies the voltage at pin 18 of IC1 from 0-5V, with clockwise rotation increasing it.

Finally, check that the IGBT is securely bolted to the case (but is electrically isolated) to ensure effective heatsinking.

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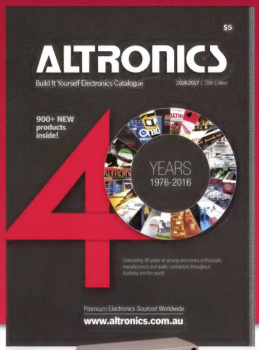

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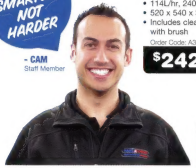

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